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No. 17683-6001-R0-00

ADVANCED STUDY OF GLOBAL OCEANOGRAPHIC REQUIREMENTS FOR EOS A/B

FINAL REPORT
APPENDIX VOLUME

Prepared for

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HEADQUARTERS
WASHINGTON, D.C.

Prepared by

TRW SYSTEMS GROUP/EARTHSAT

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CONTENTS - APPENDICES

APPENDIX A - CONPREHENSIVE GLOBAL OCEAN USER SUMMARY

APPENDIX B - SENSOR REQUIREMENTS SUMMARY

APPENDIX C - ERROR ANALYSIS FOR WIND DETERMINATION FROM GLITTER PATTERN MEASUREMENTS

APPENDIX D - COVERAGE FREQUENCY PLOTS

APPENDIX E - GROUND STATION RISE AND SET TIMES

APPENDIX F - A TECHNIQUE FOR THE REDUCTION AND ANALYSIS OF OCEAN SPECTRAL DATA

APPENDIX G - RATIONALE FOR SELECTION OF A 2 PM DESCENDING ORBIT

APPENDIX H - RELATIONSHIP TO OTHER SPACE PROGRAMS

APPENDIX I - PRIORITY ANALYSIS

APPENDIX A

Comprehensive Global Ocean User Inventory

User	Programs - Activities
Federal Government - Executive Branch	
A. Executive Office of the President	
1. The White House	
2. National Security Council	
3. Bureau of the Budget	
4. Office of Science & Technology	
5. National Aeronautics & Space Council	
6. Water Resources Council	
7. Environmental Quality Council	
B. Department of Commerce	
1. NOAA	
a. National Marine Fisheries Service	Ecological Studies of Bays & Estuaries Reduction of Fishing Costs Expand Production Opportunities Improve Efficiency of Catch King Crab Research & International Agreement Resources Management Program Ichthyoplankton Sampler Development Processing Development Technical Development & Research Aquaculture Development Programs Monitoring of Ocean Conditions Forecasting Services Remote Sensor Applications in Fisheries Marine Reserve Monitoring, Assessment & Prediction Program (MARMAP) Taxonomic Research on Selected Marine and Fresh Water Organisms Research on Estuarine Environment & Effects of Radiation & Pesticide Pollutants on Marine Life Develop Commercially Feasible Processes for Production of Fish Protein Concentrate, Formulates & Administers Contracts for Design & Operation of Experimental FPC Plants to be Constructed & Leased by the Bureau Ecological Studies of Large Oceanic Game Fish Experimental Aquaculture; Differentiation of Races of Marine Game Fish; & Translations of Foreign Fishery Literature
b. Environmental Research Laboratories	Research in physical, geological and chemical ocean phenomena
c. National Weather Service	National Weather Records Center (NWRC) Archival Center for All Climatological Data
d. Environmental Data Service	Processing, exchanging and storing global marine data and information National Oceanographic Data Center (NODC) Sound Velocity Areas Oceanographic Data Bases Ocean Data Stations Records National Marine Data Inventory (NAMIDI) World Data Center for Oceanography

User	Programs - Activities
e. National Ocean Survey	Research in Maritime Science & Technology Charts Development of Shipping Lanes Near Harbors Bathymetric Charting, Environmental Forecasting SEAMAP Program Maritime Forecast Centers Surveys
f. National Environmental Satellite Service	Operational Weather Satellites
g. NOAA Corps	Development of Environmental Salvage Technology Technical Studies of Ships Transportation Systems Analysis Polar Transportation Requirements Study Surface Effects Ships Program Data Buoy Technology Development
h. Office of Sea Grant	National Sea Grant Program Educational & Training Programs Support Program for (applied) Research Programs Marine Extension and Advisory Services Institutional Support Project Support Coherent Project Support Program Offshore Oil & Gas Studies Marine Minerals Geochemical Investigations Deep Sea Mineral Deposits Deep Sea Drilling Project
i. National Oceanographic Instrumentation Center	National Oceanographic Instrumentation Center (NOIC) Instrument Development & Testing Coordination of Instrument Development
2. National Bureau of Standards	Provides Measurement Standards Necessary for Accurate Measurement of Marine Phenomena
3. Maritime Administration	Promotes American Merchant Marine through ship construction & operating subsidy programs; federal ship mortgage insurance program, Marine Science & Technology
a. Office of Research & Development	
C. Department of the Interior	Management, conservation, & development of marine natural resources; measurement & enforcement of water quality standards, acquisition, preservation, & development of coastal areas; identification & development of technology for evaluation of mineral resources; identification of sources & interrelationships for supply of fresh water.
1. Office of Marine Resources	Project Tektite

User	Programs - Activities
2. Office of Saline Water	Mineral & Fuel Demand Analysis Technical Development Programs Mining & Processing Methods Liquid Extraction of Minerals
3. National Park Service	Underwater Parks
4. Bureau of Outdoor Recreation	Marine Parks
5. Bureau of Mines	
6. Geological Survey	Estuarine Sediment Study Marine Resource Mapping & Assessment Oceanic Research, Geological & Geophysical Research, Oceanographic Surveys, Geochemical Investigations, Submarine Geology, Aquifers, Hydraulics, EROS Program
7. Bureau of Land Management	Leases
D. Department of Transportation	Technical studies of ship construction National Navigation Plan
1. U. S. Coast Guard	High seas law enforcement Oil & other hazardous materials research Deep sea data collection Ocean weather stations
a. Science Advisor to the Commandant b. Office of Operations c. Law Enforcement Division d. Marine Sciences Division e. Coast Guard Oceanographic Unit f. International Ice Patrol g. Office of Merchant Marine Safety h. Office of Research & Development	
E. Department of Health, Education & Welfare	Biomedical aspects of underseas activities.
F. Department of State	Participation in international organizations; support of international fisheries commissions; international marine policies
1. Agency for International Development (AID)	Food-From-The-Sea Program Fish Protein Production Processing Research, Product Development Market Analyses
G. Department of Defense 1. Department of the Navy a. The Pentagon: Secretary of Navy; Under Secretary; Asst. Secretary for Installations & Logistics; Asst. Secretary for Manpower & Reserve Affairs; Asst. Secretary for Financial Management; Asst. Secretary for Research & Development; Chief of Naval Developments; Director of Navy Laboratories	
b. Office of Naval Research Navy Undersea & Development Center Naval Civil Engineering Laboratory	Studies in ship construction Surface Effects Ships Program Optimal Ship Routing Program Oceanographic Studies Bathymetric Charting

User	Programs - Activities
	Oceanographic Surveys Safety at Sea Program
	FLIr, SPAR, Sea Cliff, & Turtle, Research Vehicle Program Deep Submergence Rescue Vehicle (DSRV) Submarine Research & Engineering Sub. NR-1 Large Object Salvage Systems (LOSS) Sea Lab Experiments Project AIDTEX - Sea Ice Dynamics Drift Station Program
c. Bureau of Medicine & Surgery Submarine Medical Research Laboratory Naval Medical Research Institute Experimental Diving Unit	Biomedical Programs Man-In-The-Sea Program
d. Spacecraft Oceanography Project Office	Technical Symposia Coordination Remote Sensing Oceanographic Research
e. Naval Oceanographic Office	Fleet Numerical Weather Center (FNWC) Project Birdseye (long range ice observation) Advanced Research Projects Agency (ARPA) Arctic Capabilities Anti-Submarine Warfare Environmental Prediction Services (ASWEPS)
f. Atlantic Undersea Test & Evaluation Center (AUTEC)	
g. Office of the Oceanographer of the Navy: Director; Chief of Staff; Asst. Oceanographer for Ocean Science; Asst. Oceanographer for Ocean Engineering & Development; Asst. Oceanographer for Environmental Prediction Services; Director Programs Division; Direct Requirements Division; Director Plans & Policy Division; Director Marine Science Affairs; Director Oceanographic Center; Head Ocean Engineering & Development Division	
h. Division of Naval Reactors	Develops Nuclear Power Plants for Surface & Submarine Propulsion
i. Deputy Asst. Oceanographer of the Navy for Ocean Sciences	
j. Special Asst. for Medical & Applied Sciences a. Ocean Science & Technology Division b. Naval Research Laboratory c. Naval Arctic Research Laboratory	
k. Office of Naval Petroleum & Oil Shale Reserves	
l. Office of Naval Operations	

User	Programs - Activities
m. Navy Material Command	
a. Antisubmarine Warfare Systems Project	Development of New ASW Systems
b. Deep Submergence Systems Project	Submarine location, escape & rescue; object location, small object recovery; Man-In-The-Sea Program; large object salvage; nuclear powers deep submergence; research & ocean engineering
c. Ocean Engineering & Development Branch	Military research & engineering development in ocean technology & engineering, including meteorology, hydrology, oceanography, buoy development & ocean engineering; vehicles & sea floor construction; salvage, swimmer & diver test facilities, & environmental survey & prediction
n. Naval Air Systems Command	
o. Naval Electronic Systems Command	
p. Naval Facilities Engineering	
q. Naval Ordnance Systems Command	
r. Navy Ship Systems Command	
s. Naval Supply Systems Command	
t. Principal Naval Laboratories	
a. Naval Air Development Center	
b. Naval Civil Engineering Laboratory	
c. Naval Electronics Laboratory Center	
d. Naval Ordnance Laboratory	
e. Naval Ship Research & Development Center	
1. Naval Ship Research & Development Laboratory	
f. Naval Underwater Sound Laboratory	
g. Naval Undersea Research & Development Center	
h. Naval Underwater Weapons Research & Engineering Station	
i. Naval Weapons Center	
j. Naval Weapons Laboratory	
2. Department of the Army	
a. The Pentagon: Secretary; Under Secretary; Asst. Secretary for Financial Management; Asst. Secretary for Research & Development; Asst. Secretary for Manpower & Reserve Affairs; Asst. Secretary for Installations & Logistics; Chief of Staff; Chief of Research & Development	
b. Army Corps of Engineers	National Shoreline Study; Studies on Waste Disposal Effects; Tsunami Studies; Effects of Tsunamis; Marine Resource Mapping & Assessment; Deep Sea Mining Pilot Studies;

User	Programs - Activities
	Diving Systems; Project Tektite; Charting; Cold Regions Research (CRR); COE & CERC Data; Research, Investigation, Design, Construction, & Permit Issuance Relating to Water & Related Land Resources of Development in Coastal Areas: Commercial & Small Boat Harbors & Navigation Facilities, Beach Erosion, Recreation, Hurricane Protection, Planning Resource Management in Estuarine Areas; Mapping & Defense Activitie
c. Principal Laboratories 1. Coastal Engineering Research Center 2. Cold Regions Research Engineering Laboratory 3. Waterways Experiment Station	
d. Principal Offices 1. Lower Mississippi Valley Division 2. New England Division 3. North Atlantic Division 4. North Central Division 5. North Pacific Division 6. Pacific Ocean Division 7. South Atlantic Division 8. South Pacific Division 9. Southwestern Division	
H. National Aeronautics & Space Administration	Spaceborne & Aircraft Oceanic Research
I. Environmental Protection Agency 1. International Affairs 2. Planning & Management	
3. Standards & Enforcement	Environmental Control Program; Research & Development
4. Research & Monitoring	
5. Water Quality Office	STORET, Hydrological & related data inventory
6. Air Pollution Control Office 7. Pesticides Office 8. Radiation Office 9. Solid Wastes Office 10. Regional Offices	
J. National Science Foundation	Research on origin, structure & processes of oceans arctic programs Deep Sea Drilling Project International Decade of Ocean Exploration
K. Smithsonian Institution	Research on Marine Population & Distribution Science Exchange Program - SIE Smithsonian Oceanographic Sorting Center (SOSC) Clearinghouse for Specimens
1. Office of Environmental Sciences 2. Program Office of Ecology	

User	Programs - Activities
3. Program Office of Oceanology 4. Chesapeake Bay Center for Environmental Studies 5. Smithsonian Tropical Research Institute	
L. Atomic Energy Commission	Ecological studies of estuaries Radio nuclide fallout research
M. National Academy of Sciences 1. Committee on Oceanography 2. Committee on Undersea Warfare	
N. National Academy of Engineering	Advises Federal Government on policy & programs to utilize ocean resources, & on the engineering applications of oceanographic knowledge for welfare and defense
O. Interagency Committees 1. Interagency Committee for Marine Environmental Prediction (ICMAREP) 2. ERSPRC	
II. Federal Government - Legislative Branch A. House	Committee on Appropriations Subcommittee on State, Justice, Commerce & the Judiciary Subcommittee on Interior & Related Agencies
B. Senate	Committee on Commerce Subcommittee on Merchant Marine & Fisheries
I . State Governments	Approximately one-half of the states have coastlines fronting on the ocean or the Great Lakes & all of these have organizations relating to marine & shore affairs
A. Executive & Legislative Branches Three trends in state organization for water responsibilities are clearly discernable. One is toward the grouping of major water related functions in a single organization entity. This has meant the collection of functions which in many states are still shared by departments of health, utility commissioners, state engineers, conservation agencies, departments of agriculture, & departments of public works. The second trend is to place the water agency in a larger natural resources department, along with fish & wildlife,	

User	Programs - Activities
forestry & recreation units. A third trend is to place all environmental protection activities in a single environmental protection unit. Control of air & water pollution & regulation of solid waste disposàl are inevidably interrelated. Divisions of environmental protection or "clean air & water" seem likely to be employed increasingly. Federal governments organizations which handle oceanographic problems sometimes have their state counterpart. However, this is not always true. Due to the great diversity of state organizations, no listing of all state organizations involved in oceanographic affairs will be made.	
B. Atlantic States Marine Fisheries Commission	To promote the better utilization of the fisheries of the Atlantic seaboard by the development of a joint program for the promotion & protection of such fisheries.
1. North Atlantic Section: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut; Middle Atlantic Section: New York, New Jersey, Pennsylvania, Delaware; Chesapeake Bay Section: Maryland, Virginia; South Atlantic Sections: North Carolina, South Carolina, Georgia, Florida	
C. Gulf States Marine Fisheries Commission	To promote better utilization of the fisheries of the seaboard of the Gulf of Mexico, by development of a joint program for their promotion & protection
1. Member States: Alabama, Florida, Louisiana, Mississippi & Texas	
D. Pacific States Fisheries Commission	To inquire into methods for bringing about conservation & prevention of wastes of the fisheries over which the member states have jurisdiction; to recommend legislative or other measures furthering the purpose of the compact; & to consult & advise with the pertinent administrative agencies of the signatory states
1. Member States: Alaska, California, Idaho, Oregon & Washington	

User	Programs - Activities
IV International Organizations	
A. United Nations (UN)	The principal purposes are to maintain international peace & security; develop friendly relations among nations; achieve international cooperation in solving international economic, social, cultural, or humanitarian problems; and to be a center for harmonizing the actions of nations in attaining these common ends.
1. Advisory Committee on Marine Resources Research (ACMRR)	Advises on work concerned with research on marine fisheries resources and on fisheries aspects of oceanography.
2. Comision Asesora Regional de Pesca el Atlantico Sud-Occidental (CARPAS)	Encourages cooperation, promotes liaison & discussion particularly in the area of the Southwest Atlantic & inland waters.
3. Comite International de Geophysique (CIG)	Administers the activities of the World Data Center.
4. Committee on Fisheries (COFI)	Considers fishery problems of an international character & promotes international cooperation in fisheries.
5. Committee on Space Research (COSPAR)	Furthers on an international scale the progress of all kinds of scientific investigations carried out with the use of rockets or rocket-propelled vehicles.
6. Comite Special de l'Annee Geophysique Internationale (CSAGI)	Established World Data Centers in order to make available to the world scientific community the results of the IGY program.
7. Food & Agriculture Organization of the United Nations (FAO)	Concerned with world food supplies, human nutrition, & the well-being of rural communities.
8. Fishery Committee for the Eastern Central Atlantic (FCECA)	Intergovernmental regional body concerned with marine fisheries.
9. International Association of Biological Oceanography (IABP)	
10. International Association of Meteorology & Atmospheric Physics (IAMAP)	Promotes meteorological research & investigation.
11. International Association of Physical Sciences of the Oceans (IAPSO)	Promotes scientific study of oceanographic problems through publications; initiates & coordinates international research & scientific meetings.
12. International Council for the Exploration of the Sea (ICES)	Encourages research connected with the exploration of the sea & coordinates the activities of participating governments.
13. International Decade of Ocean Exploration (IDOE)	Promotes knowledge of the ocean, its contents & the contents of its subsoil, & its interfaces with the environment for the benefit of mankind.
14. International Geographic Union (IGU)	Promotes study of geographical problems; initiates & coordinates research requiring international cooperation; arranges international congresses; & appoints commissions for the study of special matters.
15. Intergovernmental Maritime Consultative Organization (IMCO)	Facilities cooperation among governments in technical matters affecting shipping.
16. Indian Ocean Fishery Commission (IOFC)	Intergovernmental regional body concerned marine fisheries.

User	Programs - Activities
17. Indo-Pacific Fisheries Council (IPFC)	Formulates the oceanographical, biolcgical, & other technical aspects of development & proper utilization of living aquatic resources.
18. Long Range & Expanded Oceanic Research (LEPOR)	International cooperative effort in oceanography.
19. Scientific Committee on Antarctic Research (SCAR)	Antarctic research.
20. Scientific Committee for International Biological Programme (SCIBP)	A special committee responsible to the ICSU for the International Biological Program.
21. Scientific Committee on Oceanic Research (SCOR)	Scientific advisor to UNESCO & IOC.
22. World Data Center (WDC)	Collection & distribution of data, with the responsibility for processing oceanographic data at the national level.
B. United Nations Educations, Scientific & Cultural Organization (UNESCO)	Contributes to peace & security by promoting collaboration among the nations through education, science & culture. Develops international scientific cooperations by organizing meetings among scientists, organizations, & promoting exchange of scientific information.
1. Cooperative Investigations for the Caribbean & Adjacent Regions (CICAR)	Objectives: understanding the circulation into out of, & within the Caribbean; the ocean-atmosphere interactions with particular interest in hurricanes; & the marine chemistry of the area.
2. Cooperative Study of the Kuroshio (CSK)	Synoptic & multidisciplinary surveys of the Kuroshio system; studies of the frequency & extent of the Kuroshio's short-term fluctuations; and studies of its seasonal variations
3. International Advisory Committee on Marine Sciences (IACOMS)	Organized as part of the UNESCO Natural Sciences Program.
4. Integrated Global Ocean Station System (IGOSS)	
5. International Indian Ocean Expedition (IIOE)	Survey of the Indian Ocean (including adjacent seas).
6. Intergovernmental Oceanographic Commission (IOC)	Promotes the scientific investigations of the oceans.
7. Intergovernmental Oceanographic Commission Bureau & Consultative Council (IOC/B&CC)	Steering committee
8. Pan Indian Ocean Scientific Association (PIOSA)	Studies research questions on the well-being & progress of the people dwelling on the borders of the Indian Ocean.
9. Pacific Science Association (PSA)	Initiates & promotes cooperation in the study of scientific problems relating to the Pacific region.

User	Programs - Activities
C. Other 1. Global Atmospheric Research Programme (GARP) 2. Inter-American Tropical Tuna Commission (IATTC) 3. International Commission for the Conservation of Atlantic Tunas (ICCAT) 4. International Cooperative Investigations of the Tropical Atlantic (ICITA) 5. International Geophysical Committee (IGC) 6. International Geophysical Year (IGY) 7. International Ice Patrol (IIP) 8. International North Pacific Fisheries Commission (INPFC) 9. International Pacific Halibut Commission (IPHC) 10. International Pacific Salmon Fisheries Commission (IPSFC) 11. Northeast Atlantic Fisheries Commission (NEAFC) 12. Permanent International Association of Navigation Congresses (PIANC) 13. Standing Advisory Committee on Fisheries (SAFCO) 14. World Health Organization (WHO) 15. World Meteorological Organization (WMO) 16. World Oceanic Organization (WOO) 17. World Weather Watch (WWW) 18. International Commission for the Northwest Atlantic Fisheries 19. International Whaling Commission 20. North Pacific Fur Seal Commission 21. Conference of Baltic Oceanographers (CBO) 22. Comite Consultatif International des Radiocommunications (International Radio Consultative Committee - CCIR)	These organizations in general coordinate activities, organize interested persons, and plan programs which will increase the overall knowledge of the oceanographic sciences, and provide an effective means of inter and intra-marine science communications.

User	Programs - Activities
23. Comite Consultatif International Telegraphique et Telephoniques (International Telegraph & Telephone Consultative Committee - CCITT)	
24. Comite International de Radio-Marine (International Marine Radio Association - CIRM)	
25. Commission for Maritime Meteorology (WMO)	
26. Committee on Water Research (ICSU)	
27. Declared National Program (DNP)	
28. Economic & Social Council of the United Nations (UN) - (ECOSOC)	
29. European Inland Fisheries Advisory Committee (EIFAC)	
30. Federation of Astronomical & Geophysical Services (ICSU) - (FAGS)	
31. Federation Internationale de Documentation (International Federation for Documentation - FID)	
32. General Bathymetric Chart of the Oceans (GEBCO)	
33. General Fisheries Council for the Mediterranean (GFCM)	
34. International Abstracting Board (ICSU) - (IAB)	
35. International Atomic Energy Agency (UN) - (IAEA)	
36. International Astronautical Federation (IAF)	
37. International Association of Geomagnetism & Aeronomy (IUGG) - (IAGA)	
38. International Association for Geochemistry & Cosmochemistry (IAGC)	
39. International Association of Hydrogeologists (IUGS) - (IAH)	
40. International Association of Limnology (IAL)	
41. International Association of Scientific Hydrology (IUGG) - (IASH)	
42. International Air Transport Association (IATA)	
43. International Astronomical Union (IAU)	
44. International Biological Program (IBP)	
45. International Civil Aviation Organization (ICAO)	
46. International Commission on Irrigation & Drainage (ICID)	
47. International Commission for the Scientific Exploration of the Mediterranean (ICSEM)	
48. International Council of Scientific Unions (ICSU)	
49. International Frequency Registration Board (IFRB)	
50. International Hydrographic Bureau (IHB)	

User	Programs - Activities
51. International Hydrological Decade (IHD)	
52. International Meteorlogical Organization (IMO)	
53. International Years of the Quiet Sun (IQSY)	
54. International Research Council (IRC)	
55. International Society of Biometerology (ISB)	
56. International Organization for Standardization (ISO)	
57. International Telecommunication Union (ITU)	
58. International Union of Biochemistry (IUB)	
59. International Union of Biological Sciences (IUBS)	
60. International Union for Conservation of Nature & Natural Resources (IUCN)	
61. International Union of Crystallography (IUCr)	
62. International Union of Geodesy & Geophysics (ICSU) 0 (IUGG)	
63. International Union of Geological Sciences (ICSU) - (IUGS)	
64. International Union of the History & Philosophy of Sciences (IUHPS)	
65. International Union of Pure & Applied Chemistry (IUPAC)	
66. International Union of Pure & Applied Physics (IUPAP)	
67. International Union of Physiological Sciences (IUPS)	
68. International Union of Theoretical & Applied Mechanics (IUTAM)	
69. Joint Commission on Applied Radioactivity (JCAR)	
70. Joint Organizing Committee (GARP) - (JOC)	
71. Mediterranean Association of Marine Biology (MAMBO)	
72. North Atlantic Treaty Organization (NATO)	
73. Northeast Atlantic Fisheries Commission (NEAFC)	
74. Organization of African Unity (OAU)	
75. Ocean Data Acquisition Systems (ODAS)	
76. Pan American Institute of Geography & History (PAIGH)	
77. The Permanent Service for Mean Sea Level (PSMSL)	
78. Southeast Asia Treaty Organization (SEATO)	
79. United Nations Development Programme (UN) - (UNDP)	
80. United Nations Educational, Scientific & Cultural Organization (UN) - (UNESCO)	

User	Programs - Activities
81. Union Radio Scientifique Internationale (International Scientific Radio Union - ICSU) - (URSI)	
82. World Federation of United Nations Associations (WFUNA)	
83. World Power Conference (WPC)	
V. Industry	
A. Fishing Industry Approximately 30 fisheries make up the U. S. fishing industry	The fishing industry consists of: Trade Associations; Producers; Processors; Manufacturing, Services & Support Organizations; & Distributors & Marketers.
B. Aquaculture	Farming of the sea of its biological resources
C. Processing Industry	Fish Processing
D. Non-fish Marine Food & Feed Industry	Plankton harvesting Algae harvesting Seaweed
E. Chemical Industry	Extraction of organic & inorganic compounds Magnesium Bromine Salt Other
F. Pharmaceutical Industry	Drug extraction/production Antibiotics Systemic drugs
G. Water & Power Utilities	Desalination Electric Power Generation Thermal differences, future Tidal Flows, Submerged atomic plants
H. Oil & Gas Industry	Oil & gas exploration/exploitation
I. Mining Industry	Dredging & exploration Resource Aragonite Diamonds Gold Heavy Metals Iron Iron sands Manganese nodules Phosphate Phosphate sands Sand Shell sands Shells Sulfide muds Sulfur Tin

User	Programs - Activities
	Titanium Sub-bottom mining Sulfur
J. Ocean Engineering Industry	Instruments, instrumentation Mining Technology Underwater storage Underwater structures Power sources Navigation, communication equipment Buoys & platforms Materials for marine environment
K. Shipping Industry - Transportation	Passenger Lines Cargo Shippers Bulk Carriers & Tankers
1. Ship Routing 2. Ship Building	
L. Sport & Pleasure Boating Industry	Recreation
M. Waste Disposal	
N. Trade Associations	
1. Conservation Associations	Environment & resource conservation & management. A number of organizations fall into this category.
a. American Association of Petroleum Geologists	To promote the science of geology relating to petroleum & natural gas.
b. American Bureau of Shipping	To promulgate rules for design, construction, & operation of merchant vessels, including oceanographic vessels & submersibles.
c. American Congress of Surveying & Mapping	To advance sciences of surveying & mapping
d. American Fisheries Society	To promote educational, scientific, & technological development & advancement of all branches of fishery science & practice.
e. American Geological Institute	To coordinate nonscientific work of 17 member societies in earth sciences, including publishing & business operations.
f. American Geophysical Union	To promote, coordinate,& facilitate geodesy & geophysics in the U. S., with sections specializing in geodesy, seismology, meteorology, geomagnetism & paleogeomagentism, oceanography, volcanology, geochemistry & petrology, hydrology, tectonophysics, planetology, & solar-terrestrial relationships.
g. American Institute of Biological Sciences	To advance biological, medical & agricultural sciences, their applications to human welfare, & to foster, encourage, & conduct research in biological sciences.
h. American Littoral Society	To advance study & conservation of aquatic life in the littoral zone.
i. American Malacological Union, Inc.	To promote study of ecology, systematics, & nomenclature of mollusks.

User	Programs - Activities
j. American Meteorological Society	To organize a program of publications, meetings & conferences that advance professional knowledge in meteorology & allied scientific fields
k. American Oceanic Organization	To provide a forum for oceanic topics among government, industry, press, education, & science.
l. American Petroleum Institute	To afford means of cooperation with government in matters of national concern; to foster foreign & domestic trade in American petroleum products; to promote the general interests of the petroleum industry; and to promote study of arts & sciences connected with the petroleum industry.
m. American Society of Ichthyologists & Herpetologists	To advance the study of fishes, amphibians, & reptiles.
n. American Society of Limnology & Oceanography	To promote interests of limnology, oceanography & related subjects; investigations dealing with these subjects; & publication of investigation results.
o. American Society of Naval Engineers, Inc.	To promote the knowledge of all branches of Naval engineering through meetings & publications.
p. American Society for Oceanography	To organize broad-based popular understanding of, and support for, accelerated study of world oceans & rapid development of full capacity to exploit their resources.
q. American Society of Zoologists	To present, discuss, & disseminate information in animal biology among professional zoologists.
r. American Water Resources Association	To advance water resources research, planning development, & management & to collect, organize, & disseminate information.
s. Arctic Institute of North America	To assist & cooperate in orderly scientific development of Arctic & Middle North.
t. Boston Sea Rovers	To raise level of knowledge of the underwater world.
u. Cedam International	To conduct research, archeology & related ocean sciences as hobby or avocation & to support museums established for preservation, study, & display of recovered artifacts.
v. Conservation Foundation	To conduct research, educate, improve techniques & stimulate public & private action to improve quality of environment.
w. Deep Submersible Pilots Association	To provide an effective forum for rapid & accurate exchange of information between pilots on safe operation of deep submersibles.
x. Geological Society of America	To promote science of geology by scholarly publications, meetings, assistance to research, research conferences, & other appropriate means.
y. Great Lakes Foundation	To promote public understanding of problems & facts of fresh water usage in Great Lakes Basin, & to promote scientific research.
z. Gulf & Caribbean Fisheries Institute	To contribute toward solution of industry problems in labor, sanitation standards, & inspection, culture of marine animals, & Caribbean fisheries.

User	Programs - Activities
aa. Gulf Universities Research Corp.	To perform non-profit education & research for development of Gulf of Mexico & adjacent regions as a national oceanographic resource.
bb. Institute of Environmental Sciences	To serve the professional objectives of engineers & scientists simulating & testing in earth & space environments, for betterment of mankind & advancement of industry & science.
cc. Institute of Navigation	To advance art & science of navigation in atmosphere, space, & on & under the seas.
dd. International Association for Great Lakes Research	To promote all aspects of Great Lakes research & disseminate research information.
ee. International Oceanographic Foundation	To encourage & support scientific study & exploration of the oceans & to publicize progress in marine science.
ff. International Underwater Explorers Society	To promote exploration,education, photography, & underwater recreational activities.
gg. Marine Sciences Foundation	To stimulate interest in marine sciences in Mass. secondary schools.
hh. Marine Technology Society	To establish a forum in technical aspects of ocean science, ocean engineering, & limnology; disseminate knowledge & promote education in marine sciences; encourage perfecting of devices to explore & study the ocean; & create broader understanding of relevance of marine science.
ii. National Association of Underwater Instructors	To promote safe diving through training.
jj. National Audubon Society	To promote conservation of wildlife & natural environment & to educate public on human role in natural environment.
kk. National Fisheries Institute	To represent U. S. producers, processors, & distributors of fish & seafoods.
ll. National Oceanography Association	To encourage development of a strong national ocean program for realizing potential of the seas.
mm. National Security Industrial Association	To assist Defense Dept. in solving preparedness problems through broad industry participation, advice, & counsel.
nn. National Wildlife Federation	To attain conservation goals through educational means.
oo. Navy League of the United States	To publicize conditions of naval forces & equipment of the U. S., and to stimulate interest & cooperation in aiding, improving, or developing their efficiency.
pp. Ocean Industries Association	To provide mechanisms for growth in ocean industries & for monitoring business & economic factors relating to growth.
qq. Shipbuilders Council of America	To inform members of economics, governmental, industrial, legislative, & judicial developments affecting shipyard industry of the U.S., either directly or indirectly & to provide maintenance of sound private shipbuilding & ship repair industry.
rr. Society of Exploration Geophysicists	To advance science of geophysics & art of geophysical prospecting on land & offshore.

User	Programs - Activities
ss. Society of Naval Architects & Marine Engineers	To establish a technical & professional organization for marine industry.
tt. Society for Underwater Technology	To exchange information & advance science & technology of underwater operations.
uu. Under Seas Education, Inc.	To promote all worthwhile underwater projects.
vv. Undersea Medical Society	To provide a forum for professional scientific communication among individuals & groups concerned with life sciences & human factors aspects of underseas environment.
ww. Underwater Association of Malta	To advance diving as a research tool, provide facilities for underwater research, & exchange information.
xx. Underwater Society of America	To provide national representation for & organization among divers in North America engaged in educational, scientific, and literary endeavors relating to underwater activities.
yy. United Stated Naval Institute	To contribute to professional knowledge in the Navy, primarily through publications.
zz. Water Pollution Control Federation	To advance fundamental & practical knowledge of all aspects of water pollution control through publications & to promote good public relations & sound regulations aimed toward proper water pollution control.
aaa. World Dredging Association	To establish a professional forum for executives, engineers, & others in dredging industr:
VI. Universities	There are approximately 80 universities in the United States which have oceanographic teaching & research programs; some have related laboratory facilities.
A. University of Alaska (Institute of Marine Sciences)	
B. University of Arizona	
C. University of California, Davis	Bodega Bay Laboratory
D. University of Connecticut	Marine Science Institute
E. University of Delaware	
F. Duke University	
G. Florida State University	
H. University of Florida	
I. University of South Florida	
J. Fresno State College	
K. University of Georgia	Marine Institute (Sapelo Island)
L. University of Hawaii	

User	Programs - Activities
M. Humboldt State College	
N. John Hopkins University	
O. LaMont Geophysical Laboratory	
P. Lehigh University	
Q. Long Island University	
R. Louisiana State University	
S. University of Maine	
T. University of Massachusetts	
U. University of Miami	Institute of Marine Sciences
V. University of Michigan	
W. Naval Post Graduate School	
X. City University of New York	
Y. New York University	
Z. North Carolina State University	
AA. University of North Carolina	
BB. Nova University	
CC. Old Dominion College	
DD. Oregon State University	Marine Science Center
EE. University of Oregon	
FF. University of the Pacific	Pacific Marine Station
GG. University of Puerto Rico	
HH. University of Rhode Island	Charles J. Fish Oceanographic Laboratory
II. Rutgers University	
JJ. Sacramento State College	
KK. San Diego State College	
LL. San Francisco State College	
MM. San Jose State College	
NN. Scripps Institute of Oceanography	

User	Programs - Activities
). University of Southern Mississippi	
PP. Stanford University	Hopkins Marine Station
QQ. Texas A&M University	Marine Laboratory at Galveston
RR. University of Texas	Marine Science Institute
SS. College of William & Mary	Virginia Institute of Marine Science
TT. University of Virginia	Virginia Institute of Marine Science
UU. University of Washington	Friday Harbor Laboratory
VV. Western Washington State College	
WW. University of Wisconsin	
XX. Woods Hole Oceanographic Institute	
/II. General Public	There are many individuals interested in the progress of oceanography. Some never become directly involved with the science; others continually keep up with the topic and even become members of influence groups so that they may have a direct influence on governmental policy making in matters concerning the science and its effects on our day-to-day living.

APPENDIX B

The following sensor requirement summary sheets were prepared from the sensor requirement charts of Sections 3, 4, and 5 to establish sensor design goals. In some cases the maximum and minimum goals are not identical to maximum and minimum requirements when those requirements are considered impractical or out of scope.

SENSOR REQUIREMENT SUMMARY

INSTRUCTMENT TYPE: Visible Imager

Detect, Monitor and Control Global Ocean Pollution

OBJECTIVE	ΔS IFOV (km)	S Swath Width (km)	λ_1 λ_2 Spectral Range (μ)	Δ Spectral Bandwidth (μ)	NE$\Delta\rho$ Sensitivity
I. Marine Ecosystem Modifications					
A. Power Plant Effects					
1) Current location boundaries					
a) Water color contrast	1-2	200	0.4-0.7	0.05	0.01
4) Phytoplankton dynamics	1-2	200	0.4-0.7	0.01	0.001
II. Global Temperature Alteration					
A. Albedo Modification due to haze					
1) Ice caps	5-10	- -	0.4-0.7	Broad	0.01
III. Heavy Metals					
A. Phytoplankton standing stock	10	200	0.4-0.7	0.01	0.001
B. Global Monitoring System					
1) General surface circulation					
a) Water color contrast	10	200	0.4-0.7	0.05	0.01
2) Convergences					
a) Water color contrast	20	500	0.4-0.7	0.05	0.01
3) River Plumes					
a) Water color contrast	1-2	200	0.4-0.7	0.05	0.01

SENSOR DESIGN GOALS

MAXIMUM	1-2	500	0.4-0.7	0.01	0.001
MINIMUM	10	200	0.4-0.7	0.05	0.01

INSTRUMENT TYPE Visible Imager

SENSOR REQUIREMENT SUMMARY

Monitor and Predict Physical Phenomena

OBJECTIVE	Spectral Range (μ)	Spectral Bandwidth (μ)	Resolution (km)	Swath Width FOV (km)	Sensitivity
I. Environmental Monitoring and Prediction for Transportation and Hazards					
A. Short-Term Forcing Functions					
- Basic Energy source or driving mechanisms for global environmental chgs.					
1) Insolation at sea surface					
a) Atmospheric transparency	0.4-0.7	BB	3-5	1000 SW	NE$\Delta\rho$= 0.1
B. Short-Term Coupling Mechanisms					
1) Wind stress on surface water					
a) Wind vector, fetch and duration (cloud pattern)	0.4-0.7	BB	3-5	1000	0.1
b) Directional wave wave spectrum	0.4-0.7	BB	15-30M	1000	0.1
2) Heat exchange (sensible heat)					
- Evaporation/precipitation and freezing/melting					
a) Cloud patterns	0.4-0.7	BB	3-5	1000	NE$\Delta\rho$=0.01
C. Short-Term Response Patterns					
- End manifestation of coupled energy to the earth and atmosphere					
1) Sea ice: pack and shelf formation and breakup					
c) Sea ice boundaries	0.4-0.7	BB	0.5	100	NE$\Delta\rho$=0.01
2) Regional weather conditions (fog, sea state, wind, etc.)					
c) Wind vector, fetch and duration					
- Cloud patterns	0.4-0.7	BB	3-5	1000	10%
- Wave directional spectrum	0.4-0.7	BB	15-30M	1000	NE$\Delta\rho$=0.1

INSTRUMENT TYPE Visible Imager	SENSOR REQUIREMENT SUMMARY				
	Monitor and Predict Physical Phenomena			(Page 2)	
OBJECTIVE	Spectral Range (μ)	Spectral Bandwidth (μ)	Resolution (km)	Swath Width FOV (km)	NEΔ Sensitivity
3) Currents (Response of surface waters to wind and coriolis forces					
- Current boundaries (fronts divergences, convergences, Upwelling areas					
c) Turbidity (inorganic and organic	0.4-0.7	.01	5-10	1000	NEΔ =0.01
e) Surface roughness	0.4-0.7		5-10RE	1000	NBN
D. Shoal water areas					
1) Shallow water bathymetry	0.4-0.7	.01	0.1-0.5	100	NEΔ = 0.01
2) Compression of swell wavelengths	0.4-0.7	BB	15M RE	100	NEΔ = 0.01
III. Basic Geophysical Research					
B. Geomorphology					
1) Shallow water bottom topography					
a) Bathymetry	0.4-0.7	0.01	0.5	100 SW	NEΔ = 0.01
b) Compression of swell wavelengths	0.4-0.7	BB	15 M	100 SW	
2) Volcanic Islands, Coral Reefs, Continental and Insular Coastlines					
a) Changes in configuration	0.4-0.7	0.01	0.5	100 SW	0.01
C. Conditions and Processes in Polar Regions					
1) Polar Ice pack					
a) Pack ice thickness	0.4-0.7	0.05	1 RE	100 SW	0.01
MAXIMUM	0.4-0.7	0.01	0.1-0.5	100	NEΔ = 0.01
MINIMUM	0.4-0.7	0.1	3-5	100	NEΔ = 0.01

SENSOR REQUIREMENT SUMMARY

Conservation of Living Resources

INSTRUMENT TYPE
Visible Multi-spectral Imager

OBJECTIVE	Spectral Range	Spectral Bandwidth (μ)	Resolution (km)	Swath Width FOV	Sensitivity NEΔ
I. Resource Abundance/Dynamics					
A. Total Global Resource Abundance/Yield					
1) Global primary productivity					
a) Phytoplankton pigment content	0.4-0.7	0.01	5-10	200	0.001
B. Yield potential of specific ocean sectors					
1) Regional primary productivity					
a) Upwellings					
- Phytoplankton pigments	0.4-0.7	0.01	5-10	100	0.001
- Low level cloud patterns	0.4-0.7	0.1	5-10	100-1000	0.01 (10%) NEΔT= 0.5°C
b) Seasonal convective overturn and wind mixing					
- Phytoplankton pigment	0.4-0.7	0.01	50-100	1000	0.001
d) Estuarine areas					
- Phytoplankton pigment	0.4-0.7	0.01	1-2	100	0.001
2) Environmental lethal or sublethal factors					
b) anomalous water chemistry					
- Ocean color	0.4-0.7	0.05	0.5-1	100	0.01
c) High turbidity					
- Ocean color	0.4-0.7	0.05	0.5-1	100	0.01
d) Low productivity					
- Phytoplankton pigment	0.4-0.7	0.01	5-10	100	0.001
e) Oil films/slicks					
- Ocean color	.65-1.0	0.05	0.5-1	100	0.01
II. Resource Distribution					
B. Adult Stock Migration Routes					
2) Major current/water mass displacements					
d) Phytoplankton pigment content (gradients)	0.4-0.7	0.01	1-2	1000	0.001
3) Current Meanders					
d) Phytoplankton pigment	0.4-0.7	0.01	1-2	1000	0.001

SENSOR REQUIREMENT SUMMARY

INSTRUMENT TYPE Visible Multi-Spectral Imager OBJECTIVE	Spectral Range	Sepctral Bandwidth (μ)	Resolution (km)	(FOV) Swath Width	Sensitivity NEΔ
Conservation of Living Resources (Continued)					
4) River plumes, etc					
a) Turbidity patterns	0.4-0.7	0.05	1-2	100	0.01
d) Phytoplankton pigment	0.4-0.7	0.01	1-2	100	0.001
D. Concentration of fish near discontinuities					
1) Ocean fronts					
a) Phytoplankton pigment content (gradients)	0.4-0.7	0.01	1-2	1000	0.001
2) Current eddies					
c) Phytoplankton pigment content	0.4-0.7	0.01	1-5	500-1000	0.001
III. Stock Availability/accessibility					
A. Weather effects on fishing operations					
1) Storms and squalls					
a) Cloud patterns	0.4-0.7	0.1	1-2	1000	10%
3) Icing conditions					
c) Cloud patterns	0.4-0.7	0.1	100	1000	NEΔT=0.5°C
4) Location of shoals					
a) shallow water bathymetry	0.4-.07	0.05	0.05-0.1	100	0.01
B. Vulnerbility of fish					
2) Water clarity (turbidity)					
a) Ocean color	0.4-0.7	0.05	1-5	100	0.01
SENSOR DESIGN GOALS					
MAXIMUM	0.4-1.0	0.01	0.5-1	1000	0.001
MINIMUM	0.4-0.7	0.05	5-10	100	0.01

SENSOR REQUIREMENT SUMMARY

INSTRUMENT TYPE
Glitter Camera

OBJECTIVE

Detect, monitor and control global ocean pollution

	Spectral Range (μ)	Resolution (km)	Field of View (km)
V. Chlorinated Hydrocarbons			
B. Global monitoring system			
4) Oil films	0.4-0.7	10	100

SENSOR DESIGN GOALS

	Spectral Range (μ)	Resolution (km)	Field of View (km)
MAXIMUM	0.4-0.7	10	100
MINIMUM			

INSTRUMENT TYPE
Glitter

SENSOR REQUIREMENT SUMMARY

Monitor and Predict Physical Phenomena

OBJECTIVE	Spatial Resolution (km)	FOV	Sensitivity
I. Environmental Monitoring and Prediction for Transportation and Hazards			
B. Short Term Coupling Mechanisms			
- Vehicle or process to couple energy to earth and atmosphere			
1) Wind stress on surface water			
b) Directional wave spectrum	15-30 M	1000 SW	NE$\Delta\rho$ = 0.1
c) Sea state	5 FP	50 GS	NBN
2) Heat exchange, evaporation/precipitation and freezing/melting			
f) Wind velocity (sea state)	5 FP	150 GS	± 3M/sec
C. Short Term Response Patterns			
2) Regional Weather Conditions (fog, sea state, wind, etc.)			
c) Wind vector, fetch and duration			
- sea state and swell	5 FP	50 GS	NBN
- wave directional spectrum	15-30 M	100 SW	NE$\Delta\rho$ = 0.1
3) Currents (response of surface waters to wind and coriolis forces)			
- Current boundaries (fronts, divergences, convergences, upwelling areas)			

SENSOR DESIGN GOALS

	Spatial Resolution (km)	FOV	Sensitivity
MAXIMUM / MINIMUM	5-10	1000	NBN 10%

INSTRUMENT TYPE
Glitter

SENSOR REQUIREMENT SUMMARY

Monitor and Predict Physical Phenomena (Page 2)

OBJECTIVE	Spatial Resolution (km)	FOV	Sensitivity
e) Surface roughness	5-10	1000	NBN
III. Basic Geophysical Research			
B. Geomorphology			
1) Shallow water bottom topography			
b) Compression of swell wave-lengths	15 M	100 SW	

SENSOR DESIGN GOALS

MAXIMUM

MINIMUM

SENSOR REQUIREMENT SUMMARY

INSTRUMENT TYPE Glitter			
Conservation of Living Resources			
OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Resource Abundance/Dyanmics			
B. Yield potential of specific ocean sectors			
1) Regional primary productivity			
a) Upwellings			
- Surface roughness	5-10	100-1000	NBN
2) Environmental lethal or sublethal factors			
e) Oil films/slicks -surface roughness	0.5-1	100	NBN
III. Stock Availability/Accessibility			
A. Weather effects on fishing operations			
2) Sea state and swell			
a) Sea state	10	1000	NBN
b) Directional wave spectrum	10	1000	± 10%
c) Swell wavelength/direction	100	1000	± 10%
3) Icing conditions			
b) Sea state	100	1000	NBN
4) Location of shoals			
b) Swell wavelength for shortening	0.05	100	10%
B. Vulnerability of fish			
1) Thermocline topography			
b) Internal waveslick	0.05	100	NBN

SENSOR DESIGN GOALS

	Spatial Resolution (km)	FOV (km)	Sensitivity
MAXIMUM		1000	NBN, 10%
MINIMUM	0.5-1	1000	NBN, 10%

INSTRUMENT TYPE
IR Imager

SENSOR REQUIREMENT SUMMARY

Detect, Monitor and Control Global Ocean Pollution

OBJECTIVE	IFOV (km)	Swath Width (km)	NEΔT ^{o}C
I. Marine Ecosystem Modifications			
A. Power Plant Locations and Effects			
1) Current Locations/Boundaries			
b) Surface temperature			
2) Upwellings	1-2	200	0.2-0.5^{o}C
3) River Plumes			
b) Surface temperature			
II. Global Mean Temperature Alteration			
2) Sea Surface Temperature	5 FP	150 GS	0.1
III. Heavy Metals			
B. Global Monitoring System			
1) General ocean surface circulation			
c) Surface temperature	10	200	0.2-0.5^{o}C
2) Convergences			
c) Surface temperature	20	500	0.2-0.5^{o}C
3) River Plumes			
c) Surface temperature	1-2	200	0.2-0.5^{o}C

SENSOR DESIGN GOALS

	IFOV (km)	Swath Width (km)	NEΔT ^{o}C
MAXIMUM	1	500	0.1
MINIMUM	10	200	0.2

INSTRUMENT TYPE: IR Imager				

SENSOR REQUIREMENT SUMMARY

Monitor and predict physical phenomena

OBJECTIVE	Spectral Channels	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Environmental Monitoring and Prediction for Transportation and Hazards				
A. Short-Term Forcing Functions				
o Basic energy sources or driving mechanisms for global environmental changes				
1) Insulation at sea surface				
a) Atmospheric transparency	3	3-5	1000 SW	NE$\Delta\rho$ = 0.1
B. Short-Term Coupling Mechanisms				
o Vehicle or process to couple energy to the earth and atmosphere				
2) Heat exchange (sensible heat)				
o Evaporation/precipitation and freezing/melting				
a) Cloud patterns	3 bands	3-5	1000	NE$\Delta\rho$=0.01
d) Sea surface temperature		5 FP	150 GS	NEΔT=0.2-0.5°C
g) Heat flux		50	150 GS	±10%
C. Short Term Response Patterns				
1) Sea ice: pack and shelf formation				
a) Surface temperature		5-10	100	NEΔT=0.2°C to 0.5°C ABS
2) Regional Weather conditions (fog, sea state, wind, etc.)				
b) Humidity profile	3 band	5 FP	50 GS	±0.5% RH
c) Wind vector				
Cloud patterns	3 band	3-5	1000	10%
d) Sea surface temperature		5 FP	50 GS	NEΔT=0.2°C to 0.5°C ABS
3) Currents (Response of surface waters to wind and coriolis forces)				
o Current boundaries(fronts divergences, convergences, upwelling areas)				
a) Sea surface temperature		5-10	1000	NEΔT=0.2°C to 0.5°C ABS

SENSOR DESIGN GOALS

	Spectral Channels	Spatial Resolution (km)	FOV (km)	Sensitivity
MAXIMUM	3+ bands	3-5	Full swath	NEΔT=0.2°C
MINIMUM	3 band	50	1000	NEΔT = 0.2°C

INSTRUMENT TYPE IR Imager	SENSOR REQUIREMENT SUMMARY Monitor and Predict Physical Phenomena (Page 2)			
OBJECTIVE	Channels	Spatial Resolution (km)	FOV (km)	Sensitivity
III. Basic Geophysical Research				
C. Conditions and Processes in Polar Regions				
1) Polar Ice Pack				
a) Pack ice boundaries		IRE	100SW	0.2-0.5°C ABS

SENSOR DESIGN GOALS

MAXIMUM

MINIMUM

INSTRUMENT TYPE IR Imager				

SENSOR REQUIREMENT SUMMARY

Convservation of Living Resources

OBJECTIVE	Spectral Channels	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Resource Abundance/Dyanmics				
B. Yield potential of specific ocean sectors				
1) Regional primary productivity				
a) Upwellings				
- Surface temperature		5-10	100-1000	0.5°C
- Low level cloud patterns	3 bands	5-10	100-1000	10% 0.5°C
b) Seasonal, convective overturn and wind mixing				
- Surface temperature		50-100	1000	0.2-0.5°C
d) Estuarine areas				
- Surface temperature		1-2	100	0.2-0.5°C ABS
2) Environmental lethal or sub-lethal factors				
a) Surface temperature and salinity field				
- Surface temperature		0.5-1	100	0.2-0.5°C ABS
e) Oil films/slicks				
- Surface temperature		0.5-1	100	0.2-0.5°C ABS
II. Resource distribution				
B. Adult stock migration routes				
2) Major current/watermass displacements				
b) Surface temperature		1-2	1000	0.2-0.5°C
e) Cloud patterns	3 bands	1-2	1000	0.5°C 10%
3) Current meanders				
b) Surface temperatures		1-2	1000	0.2-0.5°C
4) River plumes, etc				
a) Surface temperatures		1-2	100	0.2
5) Seasonal migrations of isotherms		5-10	1000	0.2
D. Concentration of fish near discontinuities				
1) Oceanic fronts				
a) Surface temperature		1-2	1000	0.2

INSTRUMENT TYPE IR Imager				

SENSOR REQUIREMENT SUMMARY

Conservation of Living Resources

OBJECTIVE	Spectral Channels	Spatial Resolution (km)	FOV (km)	Sensitivity
2) Current eddies				
a) Surface temperature		1-5	500-1000	0.2 -0.5°C
III. Stock availability/accessibility				
A, Weather effects of fishing operations				
1) Storms and squalls				
a) Cloud patterns	3 days	1-2	1000	10%
3) Icing conditions				
c) Cloud patterns	0.1	100	1000	10% 0.5°C
d) Surface temperature		100	1000	0.5°C
B. Vulnerability of fish				
1) Thermocline topography				
b) Internal wave slicks		0.05	100	NBN, NEΔT=0.2°C

SENSOR DESIGN GOALS

MAXIMUM	3 band	1-2	1000	0.2
MINIMUM		5-10	100	0.5

INSTRUMENT TYPE	SENSOR REQUIREMENT SUMMARY
Altimeter	Detect, Monitor and control Global Ocean Pollution

OBJECTIVE

III. Heavy Metals

B. Global Monitoring System

4) Dynamic topography 10^{-5} to 10^{-8} slopes

SENSOR DESIGN GOALS

MAXIMUM

10^{-5} to 10^{-8} slopes

MINIMUM

INSTRUMENT TYPE Altimetry	SENSOR REQUIREMENT SUMMARY Monitor and Predict Physical Phenomena		
OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Environmental Monitoring and Prediction for Transportation and Hazards			
C. Short-Term Response Patterns			
3) Currents (Response of surface waters to wind and coriolis forces)			
Current boundaries (fronts, divergences, convergences, upwelling areas)			
d) Dynamic topography	5-10	1000	1 part in 10^7

SENSOR DESIGN GOALS

	Spatial Resolution (km)	FOV (km)	Sensitivity
MAXIMUM			
	5-10	1000	10^{-7} Slope
MINIMUM			

INSTRUMENT TYPE

Altimetry

SENSOR REQUIREMENT SUMMARY

Conservation of Living Resources

OBJECTIVE	Resolution (km)	FOV	Sensitivity
II. Resource Distribution			
B. Adult Stock Migration Route			
2) Major current/water mass displacements			
a) Dynamic topography	5-10 FP	10-20 GS	10^{-5} to 10^{-8} slopes
3) Current meanders			
a) Bynamic topography	5-10 FP	10-20 GS	10^{-5} or 10^{-6} slopes

SENSOR DESIGN GOALS

	Resolution (km)	FOV	Sensitivity
MAXIMUM / MINIMUM	1-2	1000	10^{-5} to 10^{-8} slopes

INSTRUMENT TYPE
Microwave Radiometer

SENSOR REQUIREMENT SUMMARY

Detect, monitor and control global ocean pollution

OBJECTIVE	Resolution (km)	Swath Width (km)	Sensitivity
I. Marine Ecosystem Modifications			
A. Power Plant Location/Effects			
1) Current Location/Boundaries			
c) Salinity	1-2	200	0.5 0/00
3) River Plumes			
c) Salinity	1-2	200	5 0/00
III. Heavy Metals			
B. Global Monitoring System			
1) General Ocean Surface Circulation			
b) Surface Salinity	10	200	0.5 0/00
c) Surface temperature	10	200	NE ΔT =0.2-0.5°C
2) Convergences			
b) Surface Salinity	20	500	0.5 0/00
c) Surface Temperature	20	500	NE ΔT = 0.2°C
3) River Plumes			
b) Surface Salinity	1-2	200	5 0/00

SENSOR DESIGN GOALS

	Resolution (km)	Swath Width (km)	Sensitivity
MAXIMUM	1-2	500	0.5 0/00 NE ΔT =0.2-0.5°C
MINIMUM	10	200	0.5 0/00 NE ΔT =0.2-0.5°C

INSTRUMENT TYPE
Microwave Radiometer

SENSOR REQUIREMENT SUMMARY

Monitor and Predict Physical Phenomena

OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Environmental Monitoring and Prediction for Transportation and Hazards			
B. Short-Term Coupling Mechanisms			
1) Wind Stress on Surface Water			
c) Sea state	5 FP	50 GS	
2) Heat exchange (sensible heat) (Evaporation/precipitation and freezing/melting)			
a) Cloud patterns	5 FP	150 GS	NE$\Delta\rho$=0.01
b) Air temperature	5 FP	150 GS	1°C ABS
c) Humidity	5 FP	150 GS	±5% RH
d) Sea surface temperature	50	150 GS	NEΔT=0.2°C to 0.5°C
e) Sea surface salinity	50	150 GS	5 0/00
f) Wind velocity (sea state)		150 GS	I 3 M/sec
C. Short-Term Response Patterns			
1) Sea ice: pack and shelf ice formation and breakup			
a) Sea surface temperature	5-10	100	NEΔT=0.2°C to 0.5°C
b) Surface salinity	5-10	100	5 0/00
2) Regional weather conditions (fog, sea state, wind, etc.)			
c) Wind vector, fetch and duration -Sea state and swell	5 FP	50 GS	NBN
d) Sea surface temperature	5 FP	50 GS	0.2°C - 0.5°C ABS
3) Currents (Response of surface waters to wind and coriolis forces)			
- Current boundaries (fronts, divergences, convergences, upwelling areas)			
a) Sea surface temperature	5-10	1000	NEΔT= 0.2°C to 0.5°C ABS
b) Sea surface salinity	5-10	1000	0.5 0/00
e) Surface roughness	5-10	1000	NBN

SENSOR REQUIREMENT SUMMARY

Monitor and Predict Physical Phenomena (Page 2)

INSTRUMENT TYPE Microwave Radiometer OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
III. Basic Geophysical Research			
C. Conditions and Processes in Polar Regions			
1) Polar Ice Pack			
a) Pack Ice Boundaries	1	100 SW	0.2-0.5°C ABS

SENSOR DESIGN GOALS

MAXIMUM	5-10	1000	NEΔT= 0.2°C 0.5 to 5 0/00
MINIMUM	10-20	100	Salinity, NBN

INSTRUMENT TYPE
Microwave Radiometer

SENSOR REQUIREMENT SUMMARY

Conservation of Living Resources

OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
I. Resource Abundance/Dynamics			
B. Yield Potential of specific ocean sectors			
1) Regional primary productivity			
a) Upwellings			
- Temperature	5-10	100-1000	0.5°C NEΔT
- Salinity	5-10	100-1000	0.5 0/00
- Surface Roughness	5-10	100-1000	NBN
- Low leved cloud pattern	5-10	100-1000	10%
b) Seasonal convective overturn and wind mixing			
- Surface temperature	50-100	1000	0.2-0.5°C NEΔT
- Surface wind (prognosis and recent past history)	50-100	1000	
c) Coastal water masses and estuarine areas			
- Surface temperature	1-2	100	0.2-0.5°C NEΔT
- Salinity	1-2	100	5 0/00
2) Environmental lethal or sublethal factors			
a) Surface temperature and salinity field			
- Surface temperature	0.5-1	100	0.2-0.5°C NEΔT
- Salinity	0.5-1	100	5 0/00
e) Oil films/slicks			
- surface roughness	0.5-1	100	NBN
- surface temperature	0.5-1	100	0.2-0.5°C NEΔT
II. Resource Distribution			
B. Adult stock migration routes			
2) Major current/water mass displacements			
b) surface temperature	1-2	1000	0.2-0.5°C NEΔT
c) Salinity	1-2	1000	0.5 0/00
e) Cloud patterns	1-2	1000	0.5°C NEΔT
3) Current meanders			
b) Surface temperature	1-2	1000	0.2-0.5°C NEΔT
c) Salinity	1-2	1000	0.5 0/00
4) River plumes			
a) Surface temperature	1-2	100	0.2-0.5°C NEΔT
b) Salinity	1-2	100	5 0/00

SENSOR REQUIREMENT SUMMARY

INSTRUMENT TYPE: Microwave Radiometer

Conservation of Living Resources

OBJECTIVE	Spatial Resolution (km)	FOV (km)	Sensitivity
5) Seasonal migrations of isotherms			
a) surface temperature	5-10	1000	0.5°C NEΔT
D. Concentration of fish near discontinuities			
1) Oceanic fronts			
a) Surface temperature	1-2	1000	0.5°C NEΔT
b) Salinity	1-2	1000	0.5 0/00
d) Cloud patterns	1-2	1000	0.5°C NEΔT
2) Current eddies			
a) Surface temperature	1-5	500-1000	0.5°C NEΔT
b) Salinity	1-5	500-1000	0.5 0/00
III. Stock availability/accessibility			
A. Weather effects on fishing operations			
1) Storms and squalls			
a) Cloud patterns	1-2	1000	10%
2) Sea State and swell			
a) Sea state	10	1000	NBN
b) Directional wave spectrum	10	1000	± 10%
3) Icing conditions			
a) Atmospheric temperature profile	100	1000	1°C NEΔT
b) Sea state	100	1000	NBN
c) Cloud patterns	100	1000	0.5°C NEΔT
d) Surface temperature	100	1000	0.5°C NEΔT

SENSOR DESIGN GOALS

	Spatial Resolution (km)	FOV (km)	Sensitivity
MAXIMUM	0.5-1	1000	0.2°C, 0.5 0/00 NBN
MINIMUM	10-100	100	0.5°C, 5 0/00, NBN

INSTRUMENT TYPE
SLR Synthetic Aperture

SENSOR REQUIREMENT SUMMARY

Detect, Monitor and Control Global Ocean Pollution

OBJECTIVE	Resolution (km)	Swath Width (km)	Sensitivity
II. Global Mean Temperature Alteration			
1) Ice cap size	5-10		
V. Chlorinated Hydrocarbons			
B. Global Monitoring System			
4) Oil films	10	100	

SENSOR DESIGN GOALS

	Resolution (km)	Swath Width (km)	Sensitivity
MAXIMUM / MINIMUM	5-10	100	

INSTRUMENT TYPE	SENSOR REQUIREMENT SUMMARY		
SLR	Monitor and Predict Physical Phenomena		
OBJECTIVE		Spatial Resolution (km)	FOV
1. Environmental Monitoring and Prediction for Transportation and Hazards			
C. Short Term Response Patterns			
1) Sea Ice: pack and shelf ice formation and breakup			
c) Sea Ice boundaries		0. 5	100 SW

SENSOR DESIGN GOALS

	Spatial Resolution (km)	FOV
MAXIMUM	0. 5	full
MINIMUM		

APPENDIX C

Error Analysis for Wind Determination from Glitter Pattern Measurements

It was shown in Section 6.2.6 that the wind speed is given by

$$W = \frac{\tan^2\varphi - .003c}{.00512c} \qquad (1)$$

where W is the wind speed in meters per second, c is a constant $\left(\equiv \log\left[{}^{B}C/B\right]\right)$ characterizing the radiance contour to be measured, and $\tan\varphi$ is the local surface slope which reflects the sunlight to the contour. Tan φ is related to σ, the rms value of the slopes for a given wind speed, by

$$\tan^2\varphi = c\,\sigma^2 \qquad (2)$$

The measurements are made in sensor coordinates, where Θ is the angle from the center of the pattern to the chosen radiance contour. Sensor angular coordinates are related to surfaces angular coordinates by

$$\Theta = 2\varphi \qquad (3)$$

since an image point moves through twice the angle that a mirror moves. The error incurred in measuring the wind speed is given by

$$\begin{aligned}\left[E(W)\right]^2 &= GE^2 + BE^2 + ME^2 \\ &= \left(\frac{\partial W}{\partial \tan\varphi}\frac{\partial \tan\varphi}{\partial \tan\Theta}\right)^2 \left[E\ (\tan\Theta)\right]^2 + \\ &\left(\frac{\partial W}{\partial \tan\varphi}\frac{\partial \tan\varphi}{\partial B}\right)^2 \left[E(B)\right]^2 + \frac{\partial W}{\partial(\sigma^2)}^2 \left[E(\sigma^2)\right] \end{aligned} \qquad (4)$$

where tan Θ is used instead of Θ, since linear measurements on the sensor image are really measurements of tan Θ, if the center of the pattern is at the center of the image, as will normally be true of glitter sensor imagery.

Using equations 1 through 4 we can calculate the partial derivatives involved:

$$\frac{\partial W}{\partial \tan\varphi} = \frac{2 \tan\varphi}{.00512c} \tag{5}$$

$$\tan\Theta = \tan 2\varphi = \frac{2 \tan\varphi}{1 - \tan^2\varphi} \tag{6}$$

$$d(\tan\Theta) = \frac{2 (1 + \tan^2\varphi)}{(1 - \tan^2\varphi)^2} d (\tan\varphi)$$

$$\text{so } \frac{\partial \tan\varphi}{\partial \tan\Theta} = \frac{(1-\tan^2\varphi)^2}{2(1+\tan^2\varphi)} \tag{7}$$

$$B = k e^{\frac{-\tan^2\varphi}{\sigma 2}}$$

$$dB = k\left[e^{\frac{-\tan^2\varphi}{\sigma 2}}\right]\left(\frac{-2 \tan\varphi}{\sigma 2}\right) d \tan\varphi$$

$$= \frac{-2B \tan\varphi}{\sigma 2} d \tan\varphi$$

$$\text{so } \frac{\partial \tan\varphi}{\partial B} = \frac{-\sigma 2}{2B \tan\varphi} \tag{8}$$

$$\frac{\partial W}{\partial(\sigma^2)} = \frac{1}{.00512} \tag{9}$$

The error in location on the images, E $(\tan \Theta)$, attributable to vidicon non-linearities is about 1 to 2 percent of a single measurement, with proper calibration of the camera. With the multiple measurements available, it is conservative to assign $E(\tan \Theta) = 0.005 \tan \Theta$. Therefore GE can be estimated from equations 4, 5, 6 and 7, as

$$GE = \frac{1.95}{c} \tan^2\varphi \frac{(1 - \tan^2\varphi)}{(1 + \tan^2\varphi)} \tag{10}$$

The radiance error, E(B), arises from photometric errors in the vidicon, from the finite size of the sun, and from atmospheric effects. The vidicon is subject to a number of photometric errors which give rise to large absolute uncertainties which can easily amount to 10 to 15 percent. They include the difficulty of absolute calibration prior to flight and the even greater difficulties of accurate in-flight calibration to determine aging effects. Absolute photometric errors also arise from variability in exposure times and uncertainties in exact operating conditions such as temperature, supply voltages, extraneous fields, and uncertainties in the erasure of previous exposures. However, for relative measurements within a single frame, these effects almost completely

disappear. Relative errors within a frame, taking the RCA C-73496 (TIROS) vidicon as representative, arise from shading, about 1 to 2 percent of D. C. current level; pattern noise, i. e., irregular structure on the trace from a uniform exposure, also about 1 to 2 percent; and shot noise of the vidicon beam, about 0.1 percent of D. C. current level; plus a few spots, typically 1 to 3, with amplitudes of 10 to 15 percent of the D. C. current level. There is some degradation of the image during a slow scan period, but this can be compensated for quite well as long as the scan time is kept to 5 seconds or less. With practicable calibration, the sum of the relative radiance errors can be held to about 1 to 2 percent for any single measurement. The sun subtends about 0.5 degree, equivalent to about 13 km at the sea surface. For a single measurement this could produce an uncertainty in the assignment of radiance to a particular location in the order of 3 percent. Atmospheric effects are difficult to determine precisely; however, since they can be approximated roughly, since they do not change rapidly over the area of interest, and because except near the horizon they are relatively small, they will not seriously degrade relative radiance measurements. All in all, relative radiance measurements good to about ±5 percent for a single measurement can be expected. In an ideal case, about 300 center radiance measurements and at least 200 contour measurements can be made; thus about 50 available measurements for an actual case is a conservative estimate. This makes E(B) = ± .007B, and BE can be estimated as

$$BE = \frac{2 \tan \varphi}{.00512\ c} \left(- \frac{\sigma^2}{2B \tan \varphi} \right) (.007B)$$
$$= 1.37 \ \frac{\sigma^2}{c} \tag{11}$$

The model error (ME) arises from the uncertainty in the correspondence between σ^2 and wind speed, which is given by Cox and Munk as ± .004, the same for all wind speeds investigated. With an accumulation of data, verified where possible by ground truth data, it might be possible to improve the model somewhat, but for the present the above estimate is the best available. Thus the model error can be estimated as

$$ME = \frac{.004}{.00512} = 0.782 \ \text{m/sec} \tag{12}$$

independent of wind speed and conditions of measurement.

Application of equations 10, 11, and 12 gave the error estimates given in Table 6-7 of Section 6.2.6.

The estimation of the expected error in wind direction is rather difficult, but a rough idea can be obtained by calculating the size of the angular region in the vicinity of the major axis within which it is not possible to distinguish between a circle and the ellipse, given measurement errors in the determination of the ellipse itself, since the direction of the major axis can be characterized as that direction in which the curvature of the ellipse departs, in a positive sense, the most from that of a circle. In Figure C-1, the x-direction is taken to lie along the major axis, and the semi-major axis and the semi-minor axis are a and b in length respectively. The solid curve shows a quadrant of the nominal ellipse, while the dashed curve shows the ellipse given by semi-axes $a + \Delta a$ and $b + \Delta b$, Δb, where Δa and Δb are the measurement errors. The angle ϵ then, at which the distance to the oversize ellipse equals a, is the measure of the error in wind direction sought.

Thus $x^2 + y^2 = a^2$ by the hypothesis, and $\frac{x^2}{a^2 + E(a^2)} + \frac{y^2}{b^2 + E(b^2)} = 1$ by the equation for the ellipse. On the ellipse, then

$$x^2 = a^2 + E(a^2) - \frac{a^2 + E(a^2)}{b^2 + E(b^2)} - y^2$$

The best estimate for the errors is

$$\frac{E(a^2)}{a^2} = \frac{E(b^2)}{b^2} = \frac{E(W)}{W}$$

so

$$x^2 + y^2 = a^2 + a^2 \frac{E(W)}{W} - \frac{a^2}{b^2} y^2 + y^2 = a^2$$

$$\sin^2 \epsilon = \frac{y^2}{a^2} = \left(\frac{a^2}{b^2} - 1\right)^{-1} \frac{E(W)}{W}$$

$\frac{E(W)}{W}$ should include only measurement errors and not the model error,

so for $W = 10$m/sec and the 0.9 contour,

$$\frac{a^2}{b^2} = 1.425 \text{ and } \frac{E(W)}{W} = .0718$$

Therefore $\sin^2 \epsilon = .168$ and $\epsilon \approx 24^\circ$.

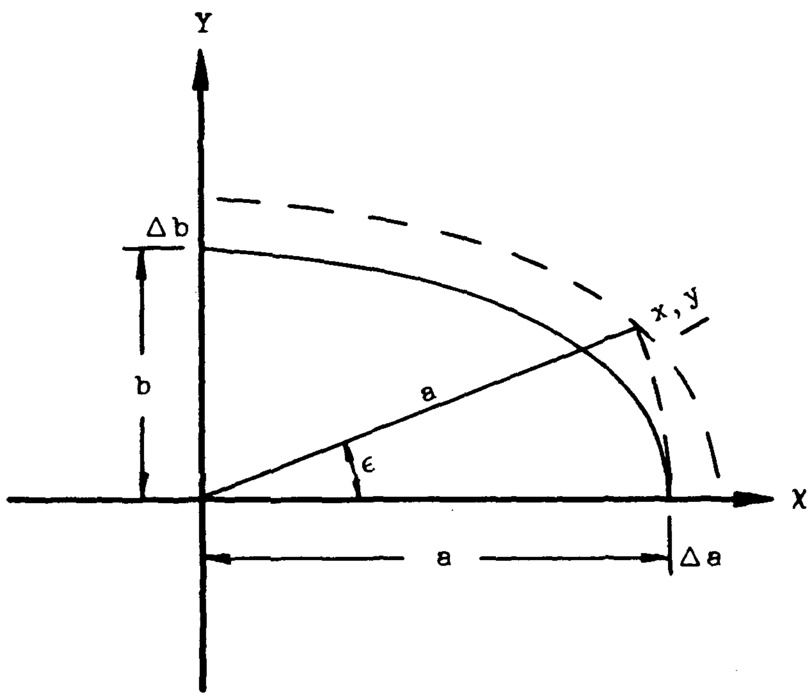


Figure C-1. Geometry for Estimating Error in Wind Direction

APPENDIX D. PLOTS OF COVERAGE FREQUENCY AS A FUNCTION OF SWATH WIDTH ARE SHOWN FOR A VARIETY OF CYCLIC FREQUENCIES

Q ($\eta = 0$)	SWATH WIDTH N MI (X 10^2)
13	16.6
14	15.4
15	14.4
16	13.5

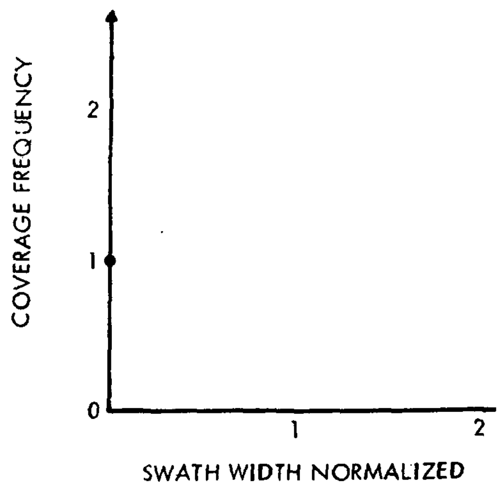


Figure D-1 One-Day Cyclic Frequency

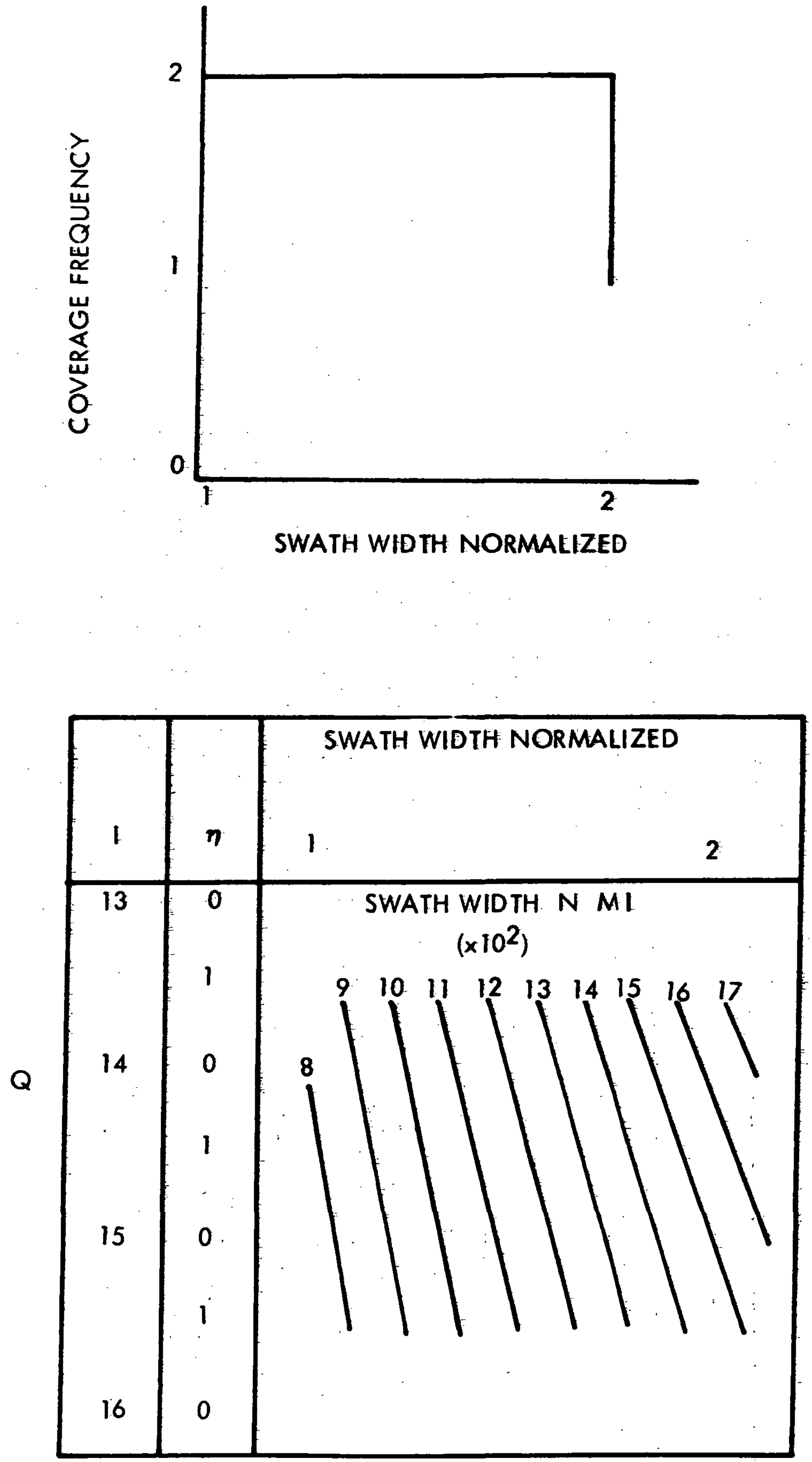
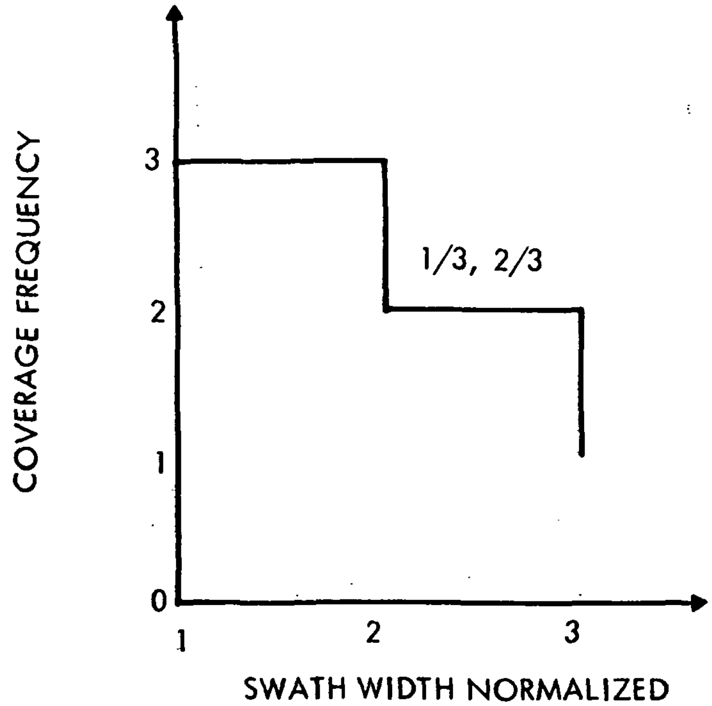


Figure D-2 Two-Day Cyclic Frequency



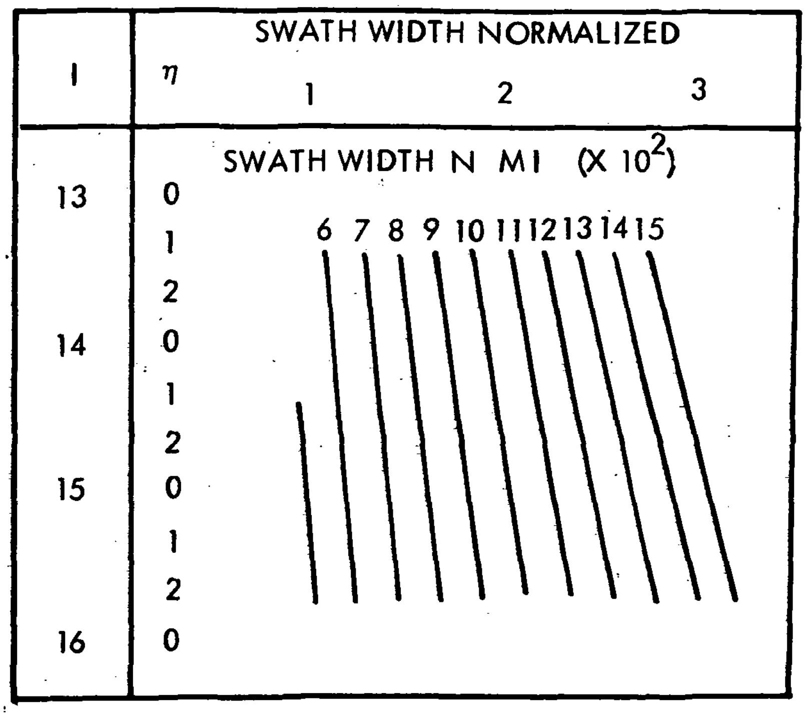


Figure D-3 Three-Day Cyclic Frequency

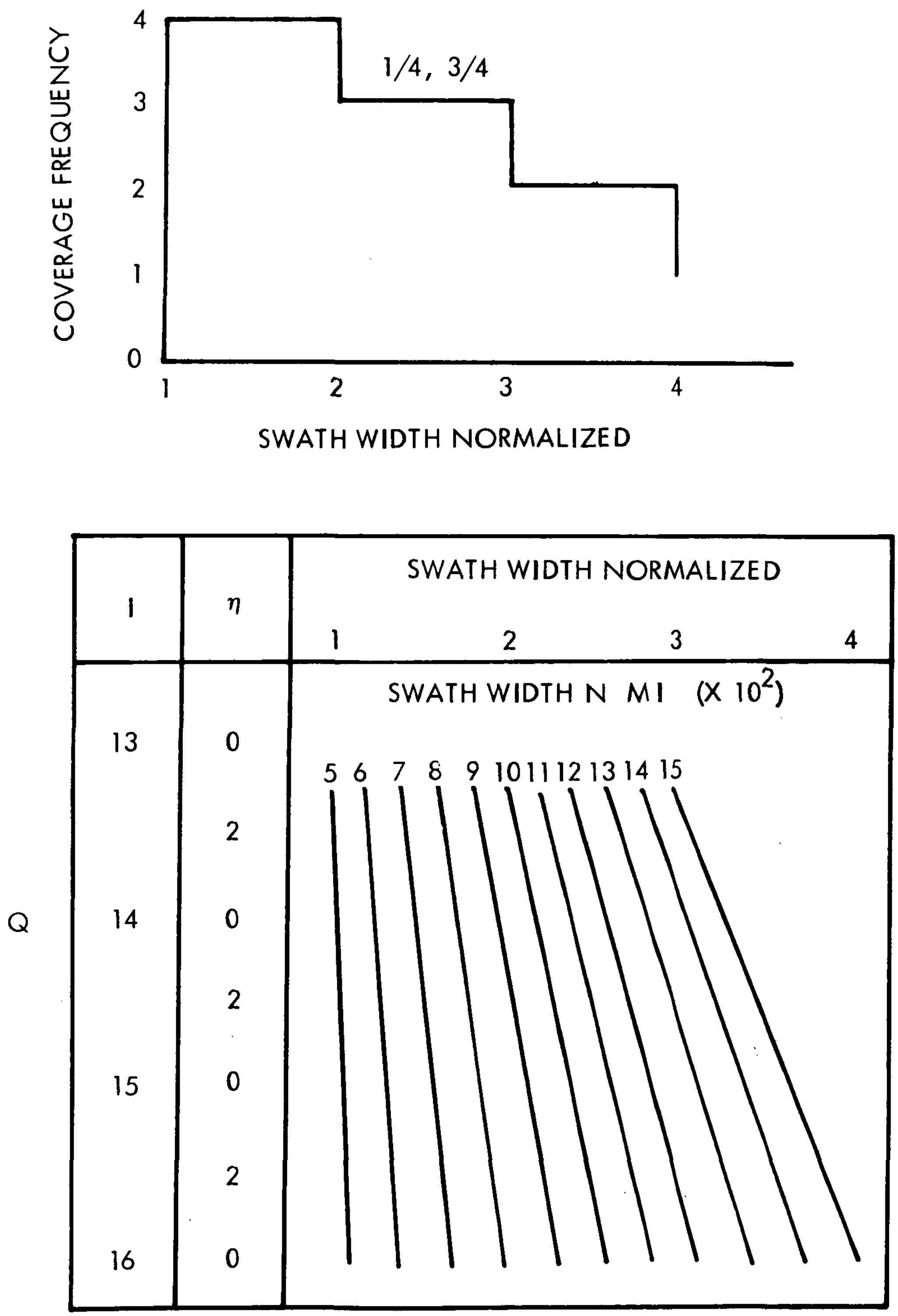


Figure D-4 Four-Day Cyclic Frequency

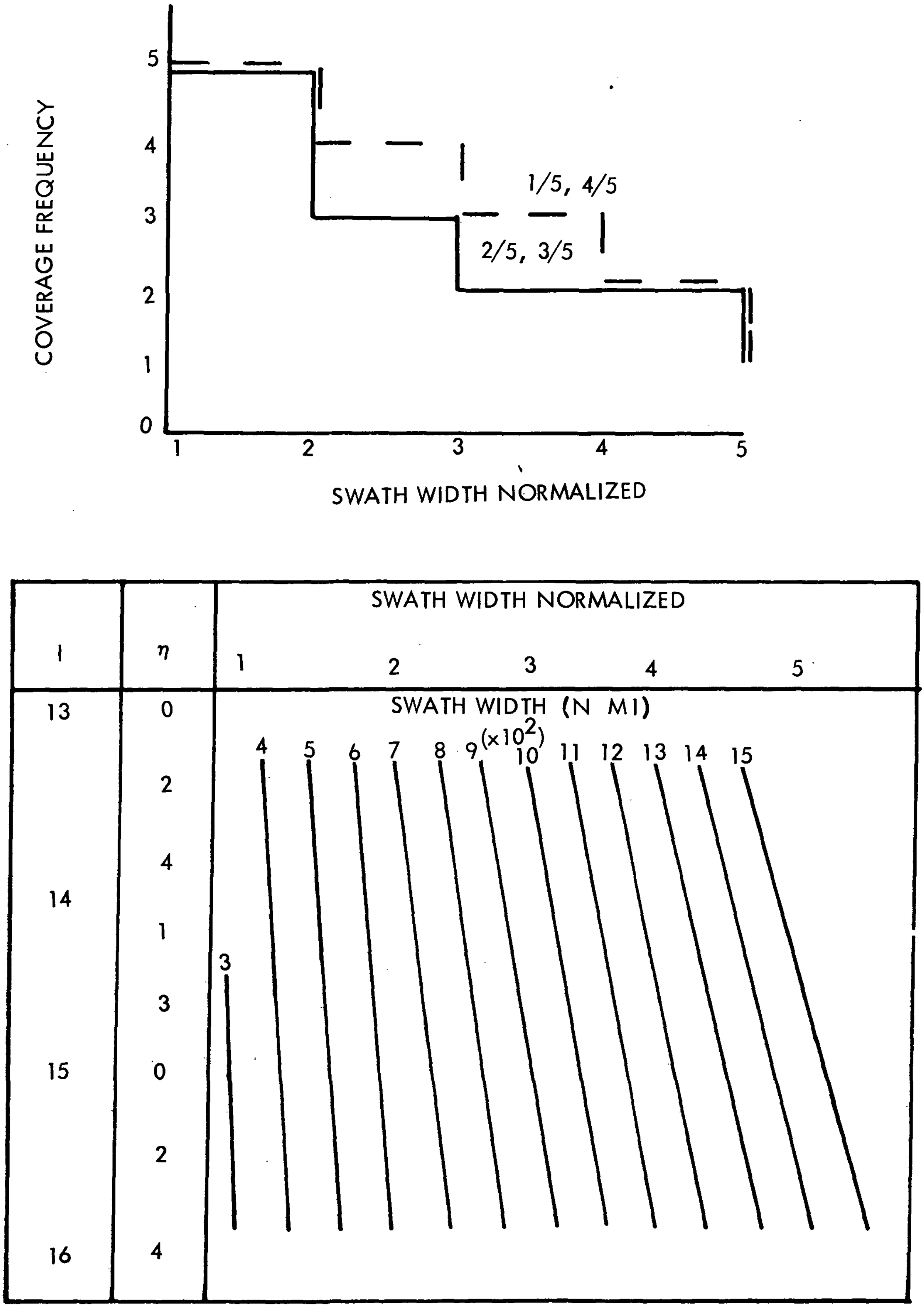
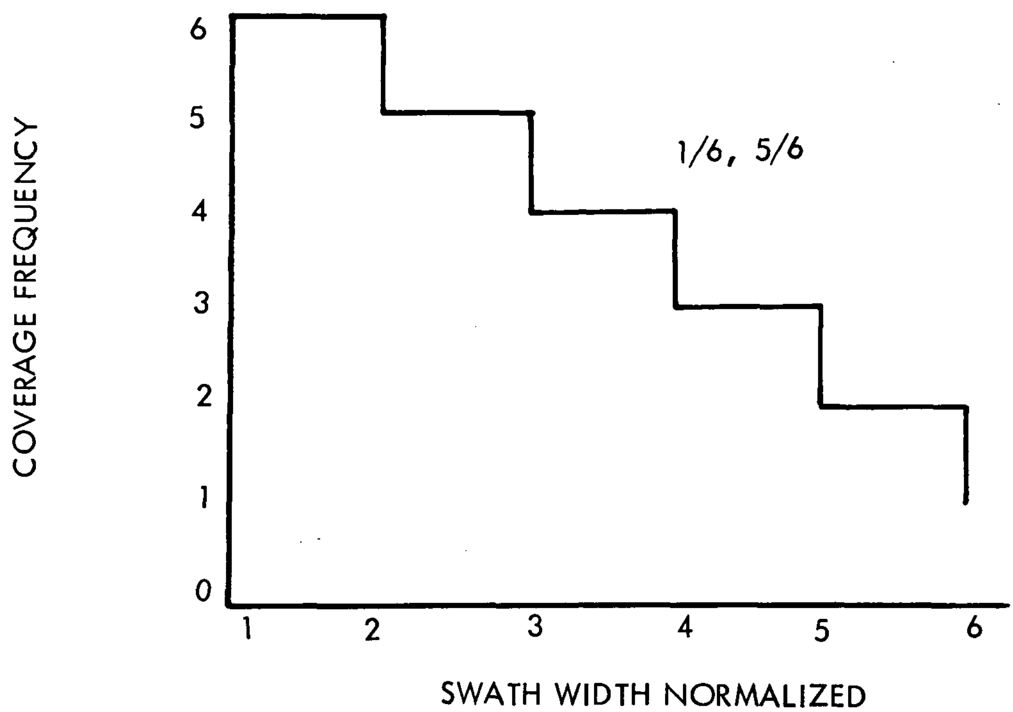


Figure D-5 Five-Day Cyclic Frequency



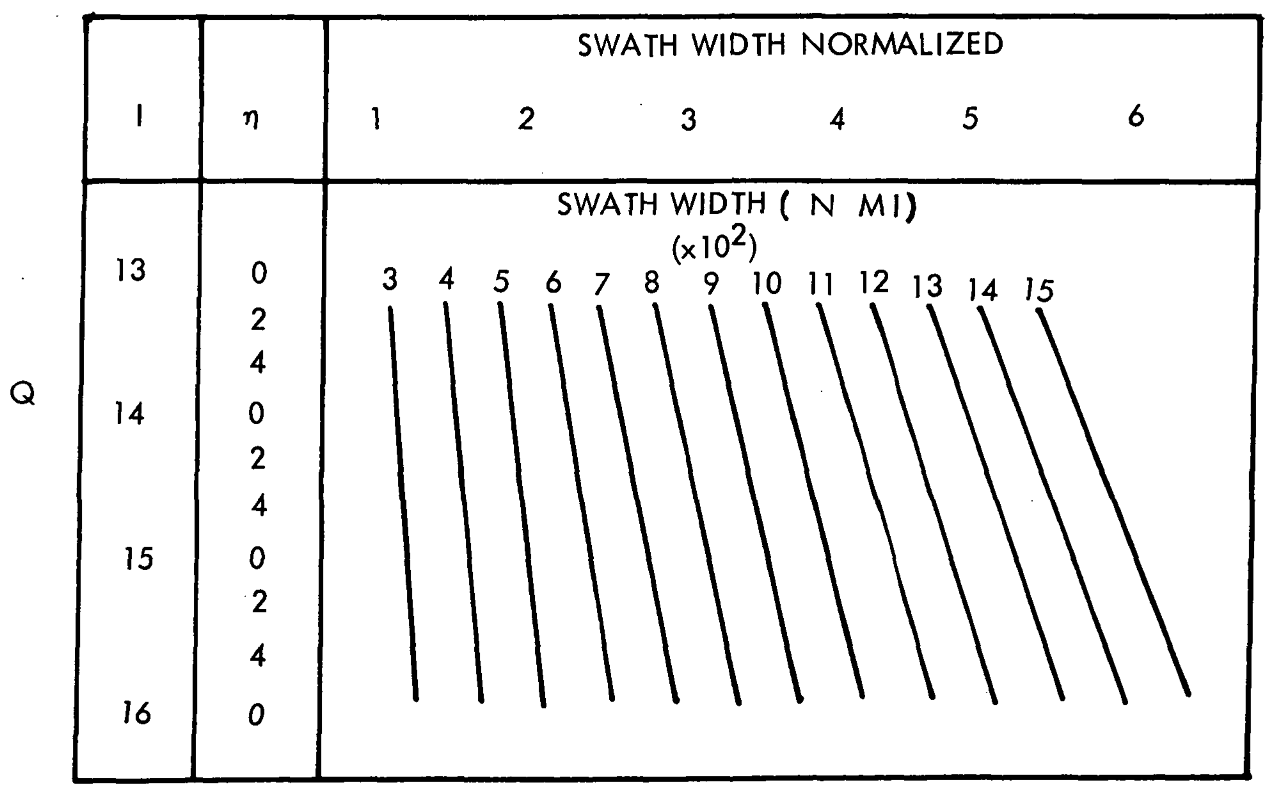


Figure D-6 Six-Day Cyclic Frequency

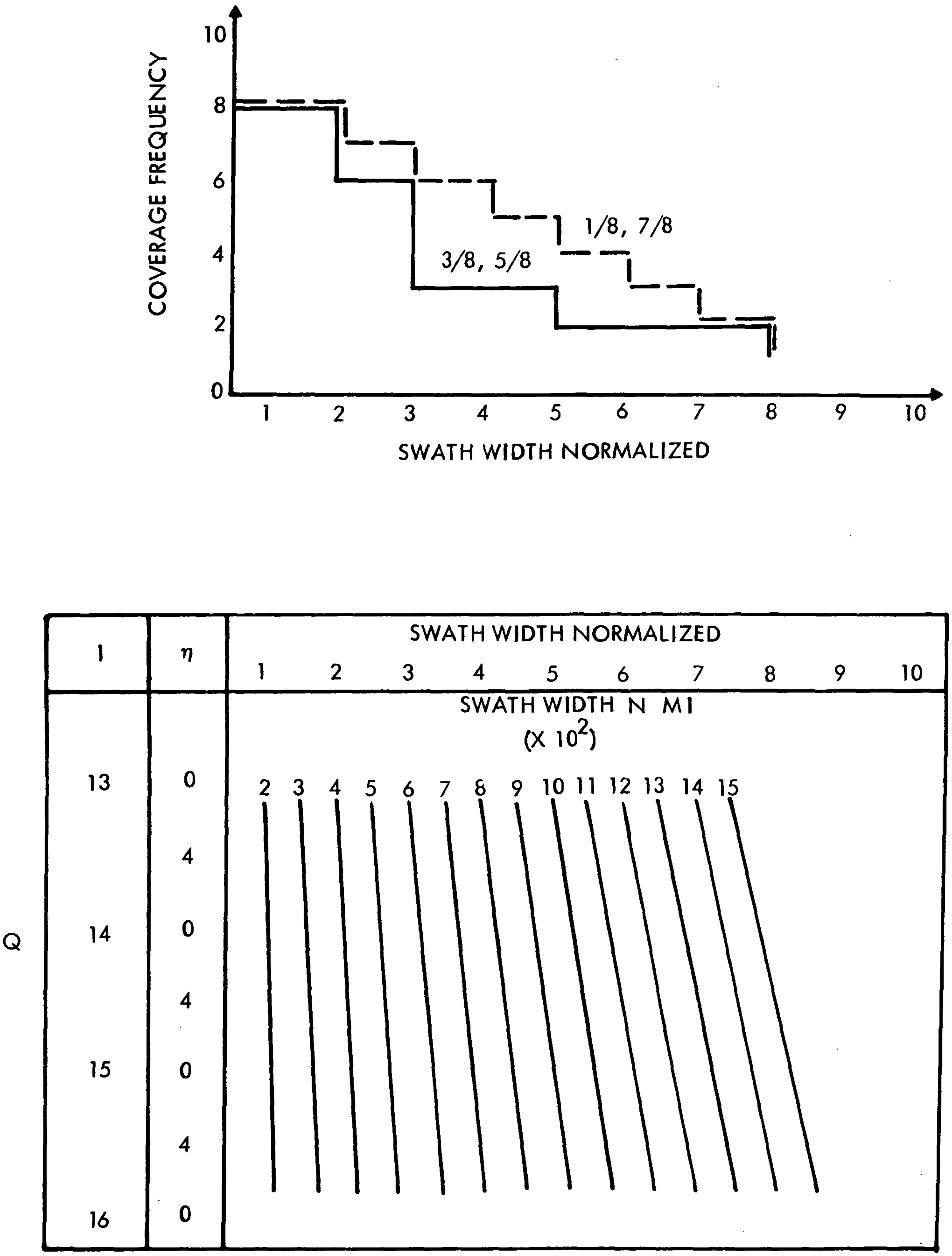


Figure D-7 Eight-Day Cyclic Frequency*

*Note: The seven day cyclic frequency case is shown in Figure 8-21 and is therefore not included in Appendix D.

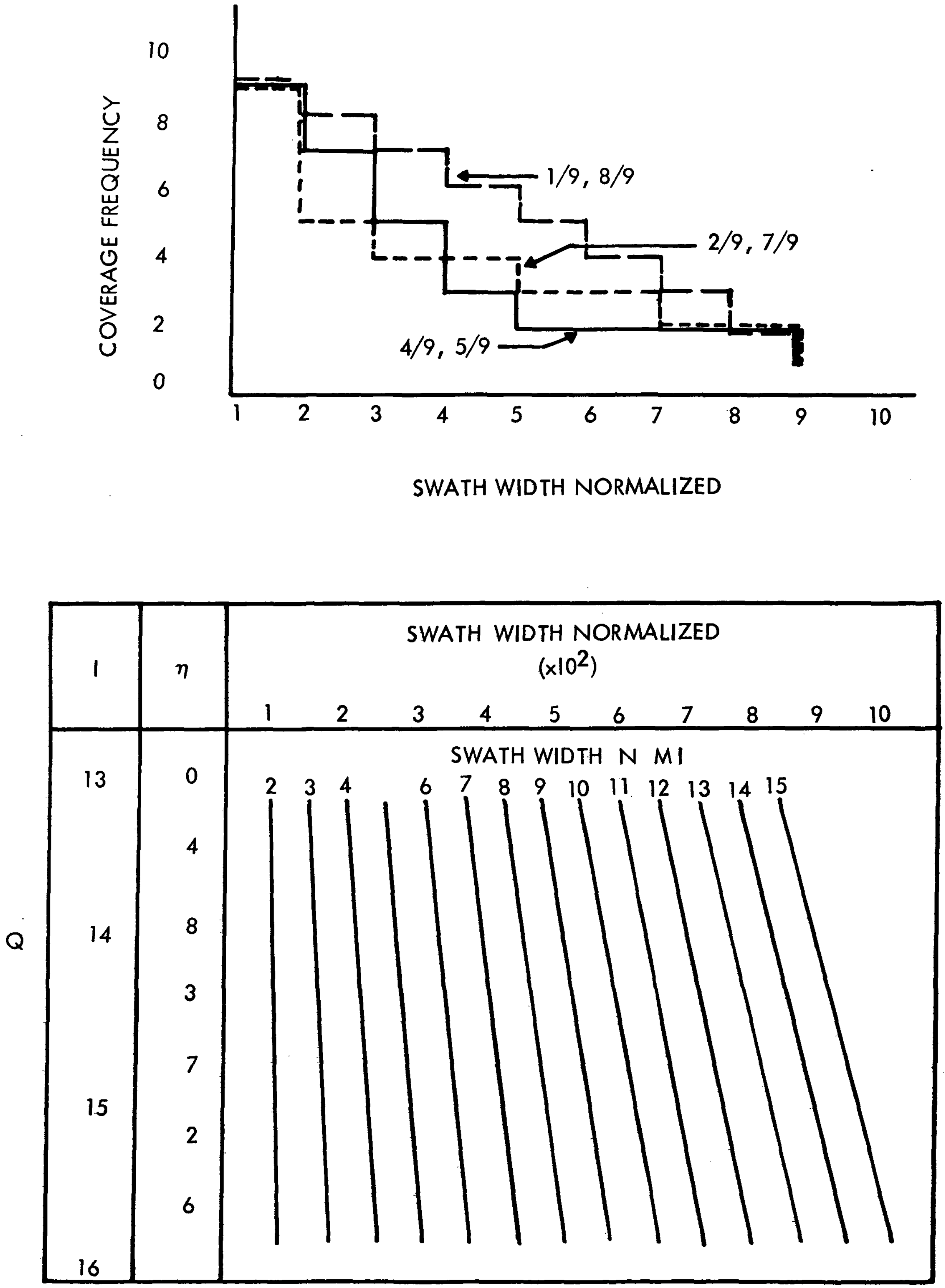
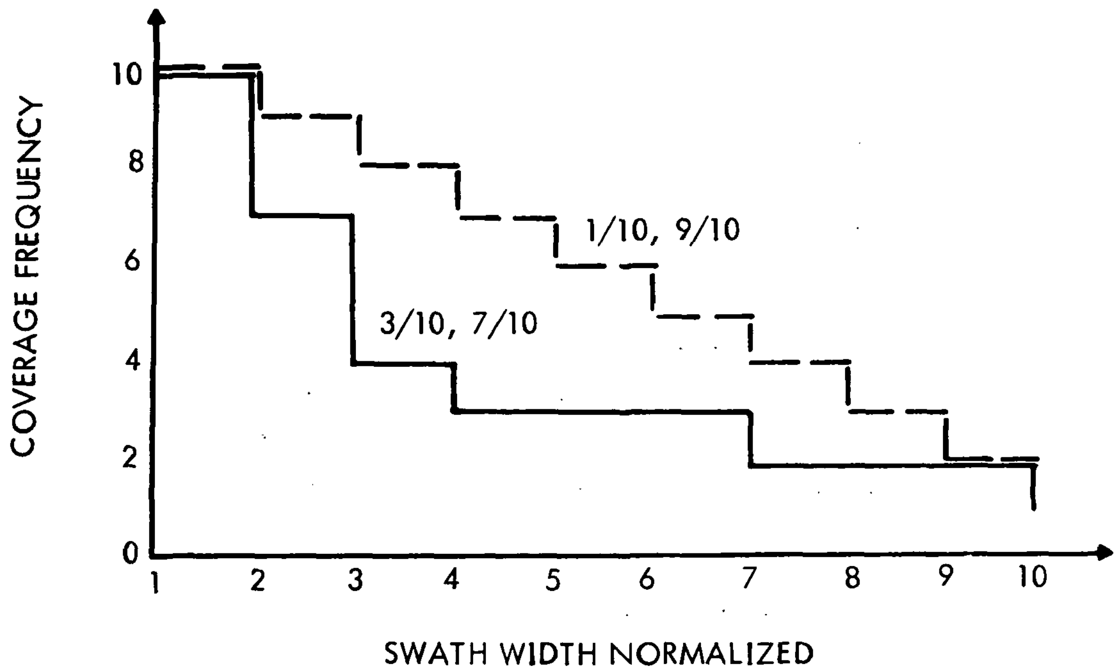


Figure D-8 Nine-Day Cyclic Frequency



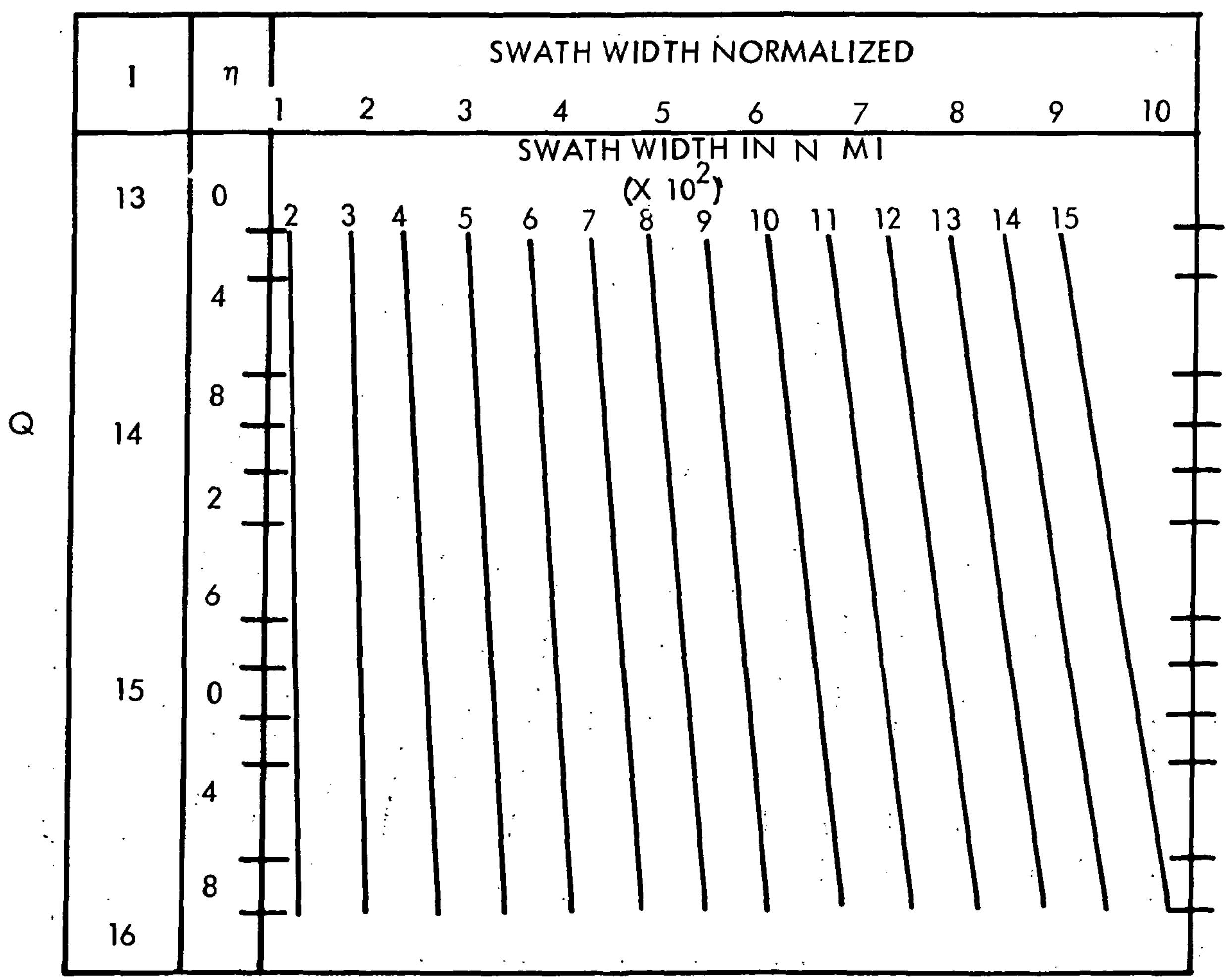


Figure D-9 Ten-Day Cyclic Frequency

APPENDIX E. GROUND STATION RISE AND SET TIMES

Stations	Orbit		
Fairbanks, Alaska	Q	=	13 3/4 orbits/day
Goldstone, California	h	=	531 nmi
Goddard Space Flight Center	i	=	99.4°
	Ω_o	=	30°
Elevation Angles	e	=	0
5° and 10°	ω	=	0

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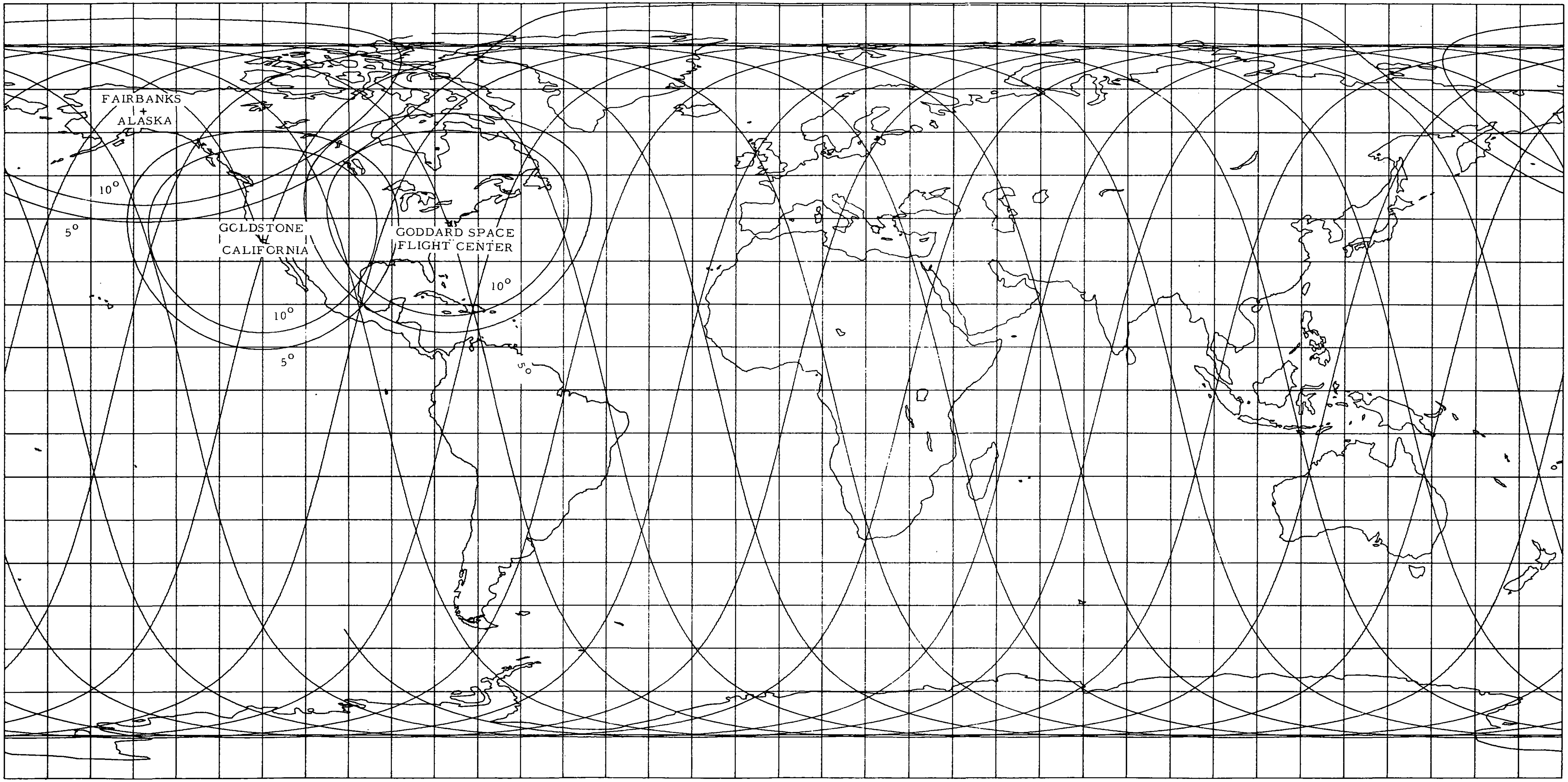

Figure E-1. Rise - Set Study Global Oceanographic Orbit
(Q = 13 3/4)

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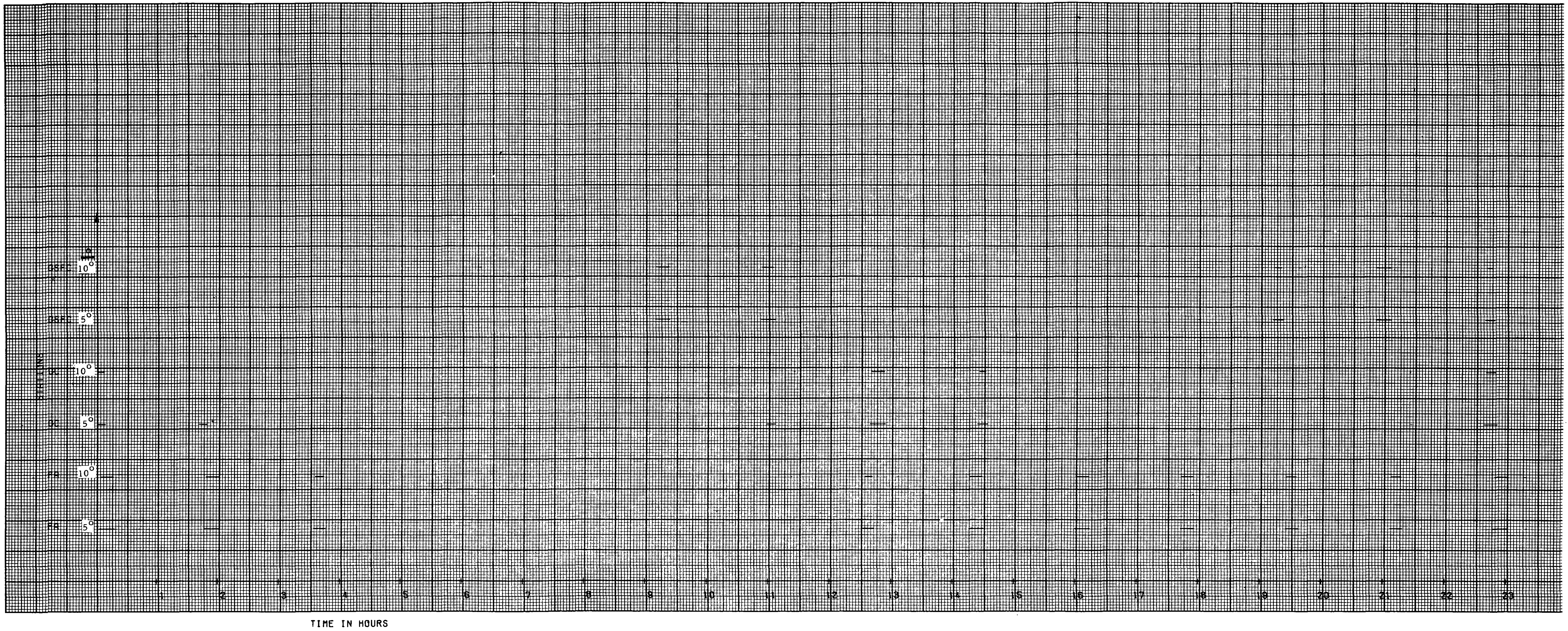

Figure E-2. Ground Station Visibility Times
(First Day)

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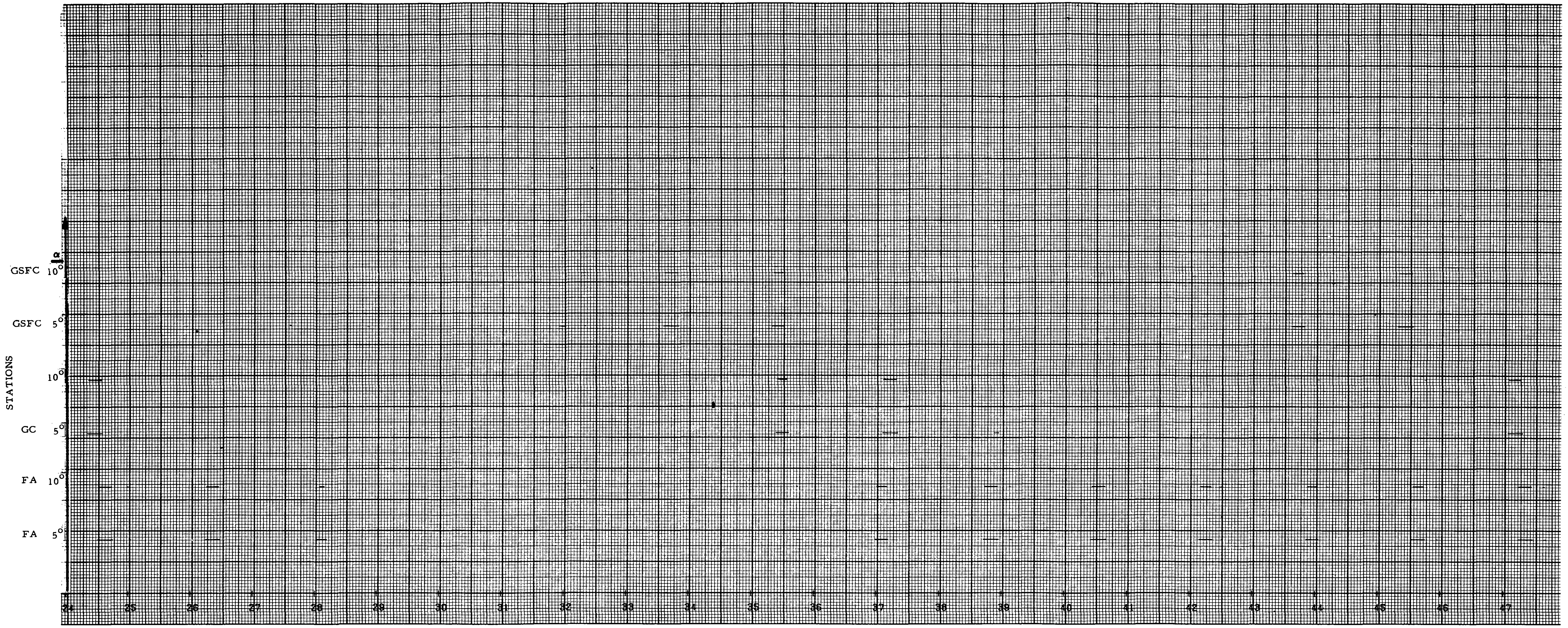

Figure E-3. Ground Station Visibility Times
(Second Day)

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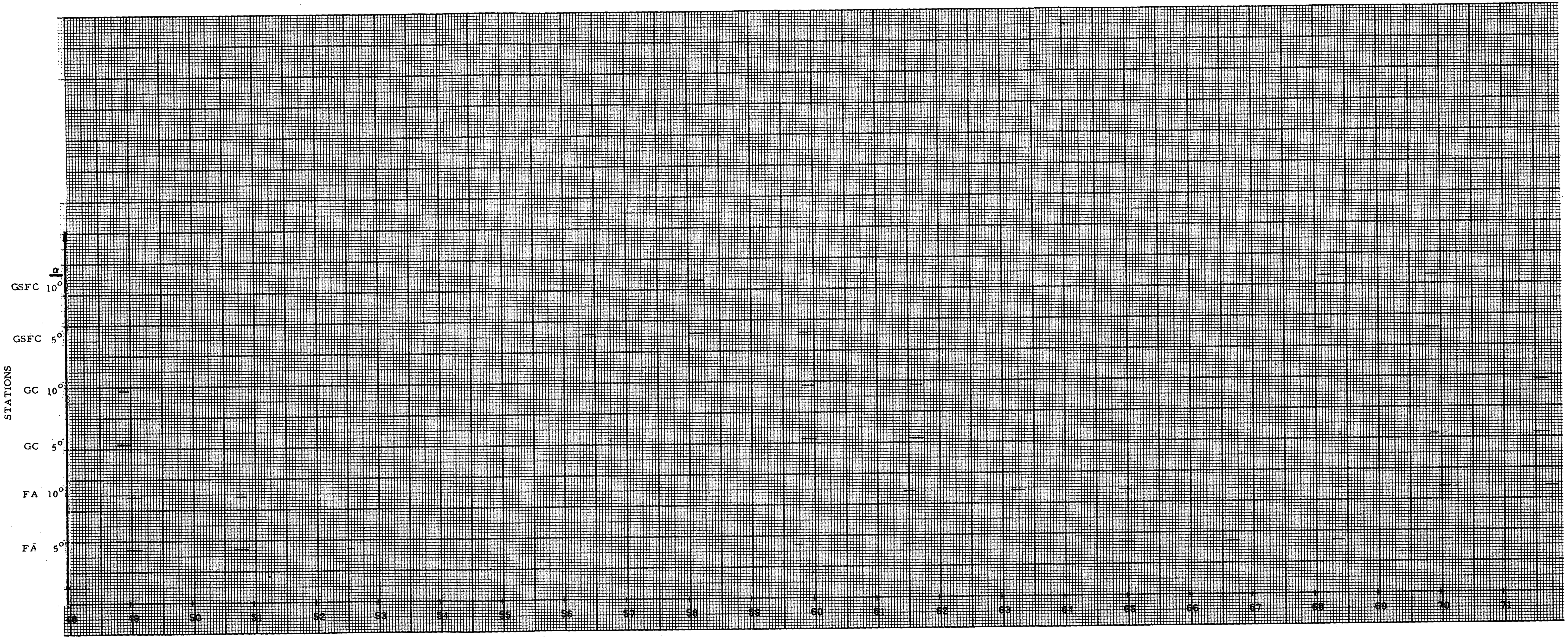

Figure E-4. Ground Station Visibility Times
(Third Day)

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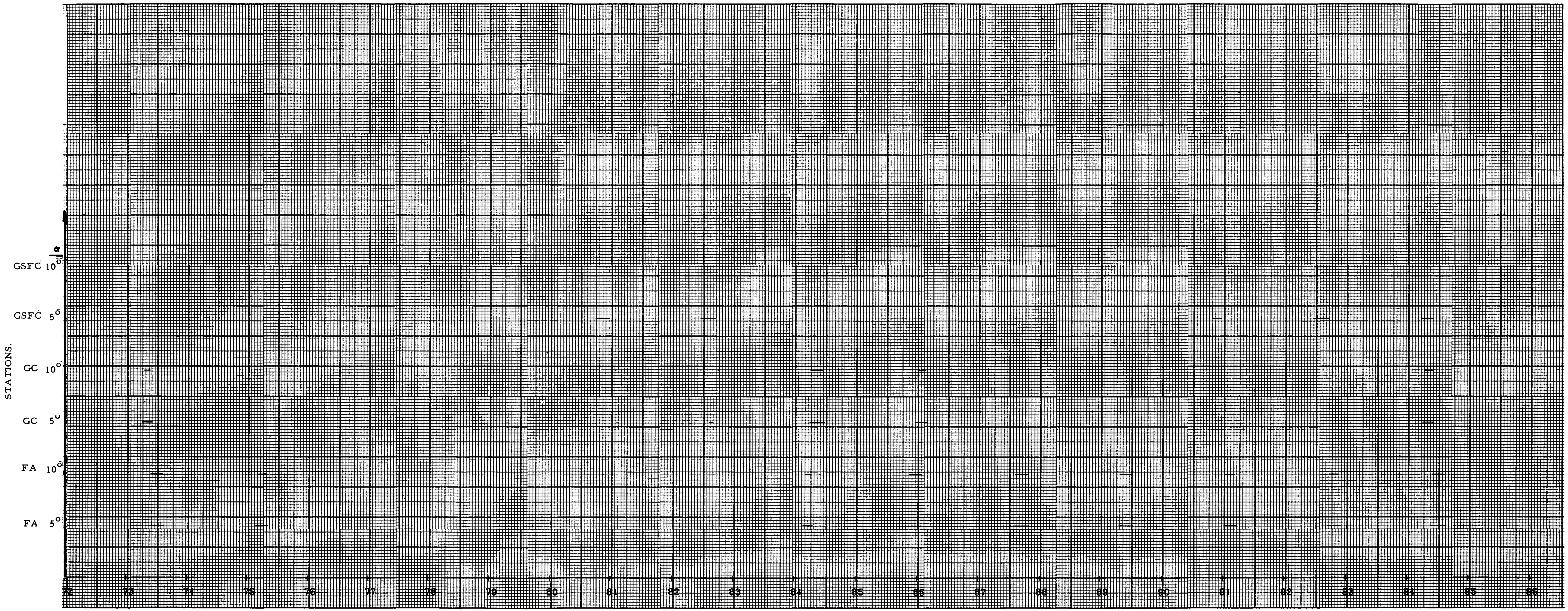

Figure E-5. Ground Station Visibility Times
(Fourth Day)

Table E-1 Rise and Set Times for a Minimum Elevation Angle of 5 Degrees

STATION Fairbanks, Alaska

LAT 64.850 LON 47.750 ALT(FT) 0.000 MIN ELEV ANGLE 5.000

REV	RISE(MIN)	LAT	LON	ALT(NM)	SET(MIN)	LAT	LON	ALT(NM)	COVERAGE(MIN)
1	2.63	43.44	236.33	525.25	16.95	80.01	131.83	519.50	14.32
2	106.23	39.53	211.52	526.03	120.47	80.56	131.23	519.46	14.24
3	212.69	45.21	183.09	524.89	223.70	78.78	133.39	519.59	11.01
8	751.37	78.26	-69.53	519.63	761.65	45.78	-114.78	524.58	10.28
9	854.50	80.49	-66.98	519.46	868.55	39.63	-143.85	526.02	14.05
10	958.02	80.19	-67.31	519.48	972.45	42.53	-169.04	525.43	14.43
11	1061.34	77.81	-70.09	519.66	1074.37	52.01	-191.08	523.53	13.03
12	1163.94	72.16	-76.73	520.23	1175.46	64.00	-208.82	521.37	11.52
13	1265.44	62.04	-89.39	521.69	1277.13	73.42	-220.37	520.09	11.69
14	1366.57	50.12	-108.00	523.91	1379.89	78.40	-226.17	519.62	13.32
15	1468.76	41.52	-130.62	525.64	1483.28	80.37	-228.54	519.47	14.52
16	1573.08	40.03	-156.33	525.94	1586.79	80.35	-228.54	519.47	13.71
17	1680.70	49.58	-186.52	524.01	1689.70	77.30	-224.87	519.71	9.00
22	2217.49	79.33	-428.35	519.54	2229.39	43.31	-483.89	525.28	11.90
23	2320.83	80.60	-426.81	519.46	2335.26	39.60	-511.53	526.02	14.43
24	2424.34	79.73	-427.82	519.52	2438.48	44.78	-535.83	524.98	14.14
25	2527.51	76.58	-431.53	519.77	2540.01	55.52	-556.79	522.86	12.50
26	2629.79	69.62	-439.71	520.55	2641.14	67.22	-572.87	520.86	11.35
27	2731.05	58.50	-454.30	522.31	2743.15	75.28	-582.59	519.89	12.10
28	2832.35	47.05	-474.26	524.52	2846.15	79.21	-587.14	519.55	13.80
29	2935.07	40.21	-497.81	525.90	2949.63	80.56	-588.92	519.46	14.56
30	3040.20	41.43	-524.53	525.65	3053.07	79.92	-588.01	519.50	12.87
31	3149.40	56.18	-557.81	522.73	3155.29	74.49	-581.59	519.98	5.89
35	3581.32	75.14	-793.18	519.91	3587.88	54.77	-819.86	523.00	6.56
36	3683.71	80.01	-787.46	519.50	3696.76	41.07	-852.42	525.73	13.05
37	3787.18	80.54	-787.02	519.46	3801.74	40.34	-878.95	525.87	14.56
38	3890.64	79.11	-788.68	519.56	3904.36	47.52	-902.34	524.43	13.72
39	3993.60	75.01	-793.33	519.92	4005.63	59.06	-922.11	522.21	12.03
40	4095.55	66.72	-803.31	520.96	4106.91	70.08	-936.34	520.49	11.36
41	4196.66	54.92	-819.66	522.97	4209.25	76.80	-944.29	519.75	12.59
42	4298.26	44.40	-840.83	525.06	4312.45	79.82	-947.88	519.51	14.19
43	4401.59	39.59	-865.27	526.02	4415.97	80.59	-948.91	519.46	14.38
44	4507.62	43.84	-893.13	525.17	4519.28	79.20	-947.12	519.55	11.66
49	5047.02	77.60	-1150.35	519.68	5056.42	48.68	-1190.70	524.19	9.40
50	5150.00	80.39	-1147.03	519.47	5163.82	39.87	-1220.53	525.97	13.82
51	5253.52	80.33	-1147.23	519.47	5268.02	41.76	-1246.10	525.59	14.50
52	5356.89	78.25	-1149.64	519.63	5370.13	50.62	-1268.56	523.81	13.24
53	5459.60	73.08	-1155.59	520.13	5471.24	62.59	-1286.93	521.60	11.64
54	5561.23	63.48	-1167.48	521.45	5572.79	72.51	-1299.31	520.19	11.56
55	5662.32	51.47	-1185.45	523.64	5675.44	77.97	-1305.79	519.65	13.12

500.04 ***

Table E-2 Rise and Set Times for a Minimum Elevation Angle of 10 Degrees

STATION Fairbanks, Alaska

LAT 64.850 LON 47.750 ALT(FT) 0.000 MIN ELEV ANGLE 10.000

REV	RISE(MIN)	LAT	LON	ALT(NM)	SET(MIN)	LAT	LON	ALT(NM)	COVERAGE(MIN)
1	3.76	47.21	234.76	524.49	15.82	80.59	155.07	519.46	12.06
2	107.41	43.49	210.05	525.24	119.30	79.41	153.84	519.54	11.89
3	214.44	51.04	180.44	523.72	221.95	74.66	153.24	519.96	7.51
8	753.34	73.33	-89.28	520.10	759.69	53.29	-111.61	523.28	6.35
9	855.70	79.09	-89.34	519.56	867.36	43.62	-142.35	525.21	11.66
10	959.15	80.54	-90.85	519.46	971.32	46.31	-167.51	524.67	12.17
11	1062.61	80.00	-90.22	519.50	1073.10	56.20	-188.68	522.73	10.49
12	1165.42	76.20	-88.53	519.81	1173.97	68.67	-203.20	520.68	8.55
13	1266.89	66.65	-94.14	520.96	1275.68	77.19	-207.05	519.72	8.79
14	1367.79	54.16	-110.13	523.12	1378.66	80.25	-205.17	519.48	10.87
15	1469.88	45.27	-132.09	524.88	1482.16	80.44	-205.02	519.47	12.28
16	1574.32	44.19	-157.91	525.10	1585.54	78.59	-206.58	519.60	11.22
17	1683.27	58.06	-191.36	522.39	1687.13	70.29	-204.45	520.46	3.86
22	2219.04	76.03	-448.57	519.82	2227.84	48.48	-481.70	524.23	8.80
23	2321.98	79.74	-449.87	519.51	2334.11	43.46	-510.09	525.25	12.13
24	2425.49	80.60	-450.85	519.46	2437.33	48.61	-534.16	524.21	11.84
25	2528.84	79.34	-449.51	519.54	2538.68	59.87	-553.83	522.06	9.84
26	2631.31	74.06	-449.04	520.02	2639.63	71.80	-565.47	520.28	8.32
27	2732.44	63.00	-457.93	521.53	2741.76	78.53	-566.63	519.61	9.32
28	2833.53	50.98	-476.10	523.74	2844.97	80.52	-564.85	519.46	11.44
29	2936.19	43.96	-499.24	525.15	2948.50	80.14	-565.44	519.49	12.31
30	3041.56	45.98	-526.33	524.74	3051.70	77.45	-567.03	519.69	10.14
36	3685.06	77.65	-808.65	519.68	3695.41	45.59	-850.65	524.82	10.35
37	3788.30	80.19	-810.36	519.48	3800.62	44.10	-877.52	525.12	12.32
38	3891.82	80.49	-810.68	519.46	3903.18	51.44	-900.47	523.64	11.36
39	3995.00	78.35	-808.88	519.62	4004.23	63.58	-918.33	521.44	9.23
40	4097.06	71.33	-810.39	520.33	4105.41	74.42	-926.74	519.98	8.35
41	4197.98	59.24	-822.51	522.17	4207.94	79.45	-926.10	519.54	9.96
42	4299.40	48.21	-842.46	524.29	4311.31	80.60	-924.86	519.46	11.91
43	4402.74	43.45	-866.71	525.25	4414.81	79.66	-925.85	519.52	12.07
44	4509.22	49.18	-895.43	524.09	4517.68	75.69	-926.97	519.85	8.46
49	5049.35	71.40	-1170.33	520.33	5054.09	56.39	-1186.55	522.69	4.74
50	5151.24	78.73	-1169.18	519.59	5162.59	43.99	-1218.98	525.14	11.35
51	5254.64	80.47	-1170.73	519.46	5266.90	45.51	-1244.62	524.83	12.26
52	5358.13	80.19	-1170.43	519.48	5368.89	54.72	-1266.36	523.01	10.76
53	5461.07	76.95	-1168.60	519.74	5469.78	67.22	-1281.96	520.88	8.71
54	5562.70	68.11	-1172.81	520.76	5571.31	76.50	-1287.02	519.78	8.61
55	5663.58	55.64	-1187.78	522.83	5674.18	80.07	-1285.42	519.49	10.60
									382.88 ***

Table E-3 Rise and Set Times for a Minimum Elevation Angle of 5 Degrees

STATION Goldstone, California

LAT 35.000 LON 20.000 ALT(FT) 0.000 MIN ELEV ANGLE 5.000

REV	RISE(MIN)	LAT	LON	ALT(NM)	SET(MIN)	LAT	LON	ALT(NM)	COVERAGE(MIN)
1	.00	34.60	239.45	526.99	7.36	59.11	228.10	522.20	7.36
2	100.22	19.25	217.57	529.47	107.90	45.13	209.39	524.91	7.68
7	657.46	44.86	-89.33	524.96	665.00	19.45	-97.35	529.45	7.54
8	757.94	59.04	-107.98	522.21	772.48	10.26	-125.92	530.36	14.54
9	862.92	58.33	-134.74	522.34	872.42	26.59	-147.94	528.41	9.50
14	1357.39	19.24	-97.58	529.47	1369.58	60.02	-114.00	522.04	12.19
15	1459.34	9.71	-121.45	530.40	1473.47	57.17	-138.24	522.55	14.13
21	2122.01	52.02	-453.70	523.53	2133.70	12.69	-466.74	530.17	11.69
22	2224.32	60.08	-474.87	522.03	2238.50	12.57	-493.03	530.18	14.18
23	2331.48	52.22	-506.13	523.49	2335.22	39.73	-511.49	525.99	3.74
28	2822.60	14.19	-463.97	530.03	2836.37	60.31	-481.91	521.99	13.77
29	2926.48	11.20	-489.49	530.29	2939.22	54.04	-504.00	523.14	12.74
35	3587.53	55.93	-819.16	522.78	3601.18	10.05	-835.07	530.38	13.65
36	3690.97	60.25	-842.42	522.00	3703.97	16.74	-859.67	529.77	13.00
41	4189.57	31.21	-810.01	527.62	4197.22	56.76	-820.80	522.62	7.65
42	4288.39	11.10	-830.89	530.30	4302.87	59.65	-849.08	522.10	14.48
43	4394.51	15.69	-858.29	529.88	4404.32	48.73	-868.96	524.18	9.81
48	4954.75	38.33	-1168.55	526.27	4958.37	26.12	-1172.32	528.48	3.62
49	5053.50	58.32	-1185.26	522.34	5067.96	9.79	-1202.81	530.40	14.46
50	5157.97	59.28	-1210.84	522.17	5168.81	23.04	-1225.70	528.95	10.84
55	5653.56	22.05	-1175.10	529.10	5664.78	59.56	-1190.43	522.12	11.22
									227.79 ***

Table E-4 Rise and Set Times for a Minimum Elevation Angle of 10 Degrees

STATION Goldstone, California

LAT	35.000	LON	20.000	ALT(FT)		C.000	MIN ELEV ANGLE		10.000
REV	**RISE(MIN)**	**LAT**	**LON**	**ALT(NM)**	**SET(MIN)**	**LAT**	**LON**	**ALT(NM)**	**COVERAGE(MIN)**
1	.00	34.60	239.45	526.99	6.24	55.44	230.54	522.87	6.24
8	759.06	55.37	-110.41	522.89	771.37	14.02	-124.99	530.05	12.31
9	864.93	51.72	-133.71	523.59	870.40	33.40	-145.92	527.22	5.47
14	1358.78	23.95	-98.83	528.82	1368.20	55.51	-110.92	522.86	9.42
15	1460.52	13.71	-122.44	530.08	1472.29	53.29	-135.90	523.28	11.77
21	2123.57	46.84	-456.17	524.56	2132.15	17.94	-465.42	529.63	8.58
22	2225.47	56.33	-477.50	522.70	2237.35	16.46	-492.06	529.80	11.88
28	2823.79	18.22	-465.00	529.60	2835.18	56.42	-479.17	522.69	11.39
29	2927.85	15.84	-490.65	529.87	2937.84	49.47	-501.63	524.04	9.99
35	3588.77	51.83	-821.48	523.57	3599.94	14.25	-834.03	530.03	11.17
36	3692.24	56.10	-845.31	522.75	3702.70	21.04	-858.55	529.24	10.46
42	4289.51	14.90	-831.83	529.97	4301.74	55.96	-846.56	522.77	12.23
43	4396.58	22.70	-860.12	529.00	4402.24	41.78	-866.07	525.59	5.66
49	5054.63	54.62	-1187.63	523.03	5066.83	13.62	-1201.87	530.09	12.20
50	5159.60	53.94	-1214.28	523.16	5167.17	28.58	-1224.15	528.08	7.57
55	5655.12	27.32	-1176.55	528.29	5663.22	54.45	-1187.07	523.06	8.10
									154.44 ***

Table E-5 Rise and Set Times for a Minimum Elevation Angle of 5 Degrees

STATION Goddard Space Flight Center

LAT 39.000 LON -77.000 ALT(FT) 0.000 MIN ELEV ANGLE 5.000

REV	RISE(MIN)	LAT	LON	ALT(NM)	SET(MIN)	LAT	LON	ALT(NM)	COVERAGE(MIN)
6	548.09	60.08	-54.67	522.03	561.85	13.99	-72.48	530.05	13.76
7	651.54	64.31	-77.19	521.32	664.71	20.44	-97.09	529.32	13.17
12	1151.07	30.09	-48.05	527.82	1161.01	63.12	-64.10	521.51	9.94
13	1251.21	14.45	-70.10	530.01	1265.75	63.04	-90.29	521.53	14.54
14	1357.99	21.27	-98.12	529.20	1367.01	51.58	-108.73	523.62	9.02
19	1914.13	46.54	-403.77	524.62	1920.08	26.53	-410.59	528.42	5.95
20	2014.12	62.25	-420.56	521.66	2028.60	13.83	-440.20	530.07	14.48
21	2118.40	63.81	-445.38	521.40	2129.69	26.26	-463.19	528.46	11.29
26	2615.72	23.16	-413.77	528.94	2628.06	64.23	-432.86	521.33	12.34
27	2717.69	13.70	-437.59	530.08	2731.92	61.33	-456.46	521.81	14.23
33	3378.37	54.71	-767.37	523.01	3389.28	18.08	-780.53	529.61	10.91
34	3480.40	63.61	-786.99	521.43	3494.84	15.39	-807.48	529.91	14.44
35	3585.72	61.82	-814.87	521.73	3593.90	34.67	-828.35	526.98	8.18
39	3986.02	51.25	-765.13	523.68	3986.35	52.34	-765.69	523.47	.33
40	4080.99	18.31	-780.17	529.59	4094.77	64.26	-800.57	521.33	13.78
41	4184.73	14.84	-805.55	529.97	4197.79	58.63	-822.07	522.28	13.06
47	4843.81	58.85	-1132.36	522.24	4857.00	14.64	-1149.09	529.99	13.19
48	4946.90	64.25	-1154.03	521.33	4960.60	18.58	-1174.35	529.55	13.70
53	5447.55	33.93	-1126.00	527.12	5456.04	62.12	-1139.97	521.68	8.49
54	5546.79	15.26	-1147.07	529.93	5561.25	63.55	-1167.55	521.44	14.46
55	5652.52	18.53	-1174.17	529.56	5663.18	54.32	-1186.99	523.08	10.66
									239.92 ***

Table E-6 Rise and Set Times for a Minimum Elevation Angle of 10 Degrees

STATION Goddard Space Flight Center

LAT 39.000 LON -77.000 ALT(FT) 0.000 MIN ELEV ANGLE 10.000

REV	RISE(MIN)	LAT	LON	ALT(NM)	SET(MIN)	LAT	LON	ALT(NM)	COVERAGE(MIN)
6	549.32	56.06	-57.46	522.75	560.63	18.12	-71.43	529.61	11.31
7	652.79	60.29	-80.77	521.99	663.45	24.70	-95.94	528.71	10.66
12	1152.94	36.39	-50.03	526.65	1159.15	57.08	-59.39	522.56	6.21
13	1252.32	18.21	-71.05	529.60	1264.63	59.42	-87.29	522.14	12.31
14	1360.47	29.66	-100.45	527.89	1364.52	43.28	-105.02	525.28	4.05
21	2119.93	58.87	-449.52	522.24	2128.15	31.46	-461.67	527.57	8.22
26	2617.08	27.75	-415.05	528.22	2626.70	59.85	-429.03	522.07	9.62
27	2718.85	17.63	-438.58	529.67	2730.75	57.52	-453.62	522.48	11.90
33	3380.12	48.91	-770.39	524.15	3387.55	23.94	-778.98	528.82	7.43
34	3481.53	59.96	-790.12	522.05	3493.72	19.18	-806.51	529.48	12.19
35	3588.54	52.59	-821.08	523.42	3591.07	44.17	-824.96	525.10	2.53
40	4082.18	22.34	-781.23	529.06	4093.58	60.43	-797.15	521.97	11.40
41	4186.04	19.28	-806.69	529.47	4196.46	54.26	-819.28	523.10	10.42
47	4845.12	54.55	-1135.14	523.04	4855.70	19.04	-1147.97	529.50	10.58
48	4948.10	60.39	-1157.47	521.97	4959.40	22.64	-1173.28	529.01	11.30
53	5450.10	42.50	-1128.97	525.44	5453.50	53.82	-1134.18	523.18	3.40
54	5547.91	19.05	-1148.04	529.50	5560.13	59.94	-1164.45	522.05	12.22
55	5654.32	24.62	-1175.79	528.72	5661.37	48.32	-1183.92	524.27	7.05

175.01 ***

APPENDIX F. A TECHNIQUE FOR THE REDUCTION AND ANALYSES OF OCEAN SPECTRAL DATA

INTRODUCTION

One of the most difficult problems associated with the interpretation of remote spectral measurements of the ocean is the separation of atmospheric effects from the signal which originates in the water. The total signal received by a high altitude aircraft or spacecraft contains information originating in both the water itself and the atmosphere, with the latter predominating.

Because the user of these data is interested in the difference between the spectral radiance of various bodies of water, he finds it necessary to measure small percentage differences in radiance, even though the basic differences in the signal from the water bodies may be substantial. This is illustrated by the following:

$$S_T = S_A + S_W$$

where S_T, S_A and S_W are the signal received at the sensor, and the individual components from the atmosphere and the water, respectively. S_A is large compared to S_W; typically larger by a factor of 10 in the case of a spacecraft measurement. Thus an uncertainty of 1% in S_T can result in an uncertainty of 10% in deriving S_W. This imposes severe accuracy and sensitivity requirements on the measurement of S_T and on the calibration of the instrument which makes these measurements.

The following paragraphs describe some initial investigations of a method of reducing and analyzing raw ocean spectral data which avoids most of the problems associated with atmospheric effects, and which requires the application of little if any calibration information to the data.

ANALYSIS OF RAW SPECTRAL DATA

Figure 1 shows unreduced spectral curves of two bodies of water as sensed from 1,000 ft. altitude. The data are in arbitrary units and are described by the following:

$$S_\lambda = [IR(\rho_W\tau + \rho_A)]_\lambda\, G$$

where

S_λ is the ordinate of Figure 1

I is the solar spectral irradiance at the ocean surface

R is the spectral response of the measuring instrument

ρ_W is the spectral reflectivity of the ocean

ρ_A is the effective spectral reflectivity of the atmosphere

τ is the spectral transmission of the atmosphere from the surface to the measurement altitude

G is an instrument conversion factor.

The data were taken with a rapid scanning spectrometer and the curves of Figure 1 represent the analog output of the instrument. The spectrometer has a spectral resolution of 10 nm. Figure 2 shows spectral curves of the same two water bodies as measured from 25,000 ft. altitude.

A comparison of the two figures shows that differences between the two water bodies are much more apparent at the lower altitude (Figure 1). At higher altitude (Figure 2) the additive light backscattered by the atmosphere significantly reduces the percentage differences between the curves. In spite of this, features due to differences between the two types of water may be distinguished on Figure 2 as well as Figure 1.

In order to enhance these differences and at the same time reject the information contained in the general shape of the curve (spectral response of the instrument, spectral irradiance of the sun, and atmospheric radiance) the second derivative of each of the four curves has been calculated and plotted in Figures 3 and 4.

Note that certain features of the derivative curves appear to be relatively independent of altitude.

In order to identify spectral regions which are most sensitive to changes in water color and least sensitive to atmospheric effects, the following technique has been used to isolate the relative effects of each.

Figure 5 is a plot of the difference in second derivatives ($S''_B - S''_A$) of the two types of water (identified as A and B for convenience). Note that the curves are strikingly similar regardless of altitude. Similarly Figure 6 is a plot of the difference of the second derivatives of the two altitudes ($S''_{1000} - S''_{25,000}$). The similarity between the curves here is even more marked, indicating that we have successfully isolated the effects on the second derivative of water color (Figure 5) and atmosphere (Figure 6).

In order to determine the spectral regions in which water color effects on the second derivative predominate over atmospheric effects, Figure 7 has been prepared showing the subtractive difference between the curves of

Figures 5 and 6. Those portions of the curve below zero (atmospheric effect greater than water color effect) have not been plotted. Regions of maximum difference are centered at 486, 570, 604, and 655 nanometers. It *is suggested that second derivatives of raw spectral curves be evaluated* at these wavelengths in order to minimize atmospheric effects and give maximum information about the water type. However it is probable that other types of water will yield additional wavelengths well suited for discrimination.

PRACTICAL CONSIDERATIONS IN USING THE TECHNIQUE

As stated earlier, the spectral resolution of the raw data is 10 nm. In order to determine the effect of spectral resolution on the technique, the raw data was degraded to 30 nm resolution by passing a "moving window" numerical filter of 30 nm width over the data and then again calculating the second derivatives. Figure 8 is an example of the 30 nm raw data compared to the 10 nm data. There is a general smoothing of the curve at 30 nm.

Figure 9 shows the second derivatives of the Figure 8 (30 nm resolution) data. A measure of the information lost by degrading the resolution from 10 to 30 nm is the difference in amplitude of the curve from 570 to 604 nm. On this basis the information lost (amplitude reduction) is 21%.

In calculating the second derivative, another spectral filter is used in the calculation as follows:

$$S''_{\lambda+\beta/2} = (S_{\lambda}-S_{\lambda+\beta}) - (S_{\lambda+\Delta\lambda}-S_{\lambda+\Delta\lambda+\beta})$$

where β is the spectral bandpass of the filter and $\Delta\lambda$ is wavelength interval between calculations (5 nm in the examples given). All of the previous examples have used a β of 30 nm. This appears to be approximately optimum to maximize differences between the curves, but for comparison, Figure 10 shows the effect of reducing β to 10 nm. Considerably more structure is apparent in the curve, but it is not clear at this time how much is due to Fraunhoffer lines, atmospheric absorptions and noise as opposed to water color information.

The effect of increasing $\Delta\lambda$ to 15 nm from 5 nm (decreasing sampling rate by a factor of 3) is shown in the second derivative plots of Figure 11. The advantage of maintaining $\Delta\lambda$ at 5 nm is obvious.

Another important factor in using this method is the need for data which has been acquired in a "moving window" type of spectral scan as opposed to individual detectors located in each of the spectral bands. A moving window scan is one in which an aperture, whose width defines the spectral resolution is moved at a constant velocity over the spectrum to be analyzed. If this is not done (i.e., if separate detectors are located in different regions of the spectrum) then it is necessary to mathematically fit a curve from point to point through the spectrum to reduce $\Delta\lambda$. The characteristics of the equation used to fit the curve will then have a strong undesirable influence on the second derivative.

MEASUREMENT SENSITIVITY

The potential sensitivity of the second derivative technique can be illustrated by comparing data from the two bodies of water shown in Figure 2 as measured from 25,000 ft. altitude. Although the actual content of plankton in each type of water is not known exactly, surface truth measurements established that the type A water contained approximately ten times the plankton of type B. If we consider the excursion of the second derivative from 570 to 604 nanometers to be an indicator of plankton content, then the value of this indicator increased by 3.7 times from type B to type A. This suggests a non-linear relationship between the indicator and the plankton content, and/or a positive value of the indicator when the plankton count is zero. However, the maximum apparent noise or scatter on the derivative curves is less than one part in 50 of the range of the indicator which implies that the water may be categorized into some 25 levels between the limits shown. It is not expected that the clarity or haze content of the atmosphere will have an appreciable effect on these accuracies for sun zenith angles of less than 40° and viewing angles less than 10° off the nadir.[1]

CONCLUSIONS

1. The analysis technique described is capable of distinguishing fairly subtle differences in water color from data which has been measured through an atmosphere with at least half the optical density of the earth's total atmosphere.

2. The technique does not require the application of calibrations to the raw data, other than a simple correction for solar elevation angle.

3. Data obtained at 30 nm spectral resolution has about 20% less information content than data with 10 nm resolution.

4. Data should be obtained with a single "moving window" type spectral scan, with individual digitized samples about 5 nm apart.

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1 R. S. Fraser and R. C. Ramsey, "Nadir Spectral Radiance of the Sunlit Earth as Viewed from above the Atmosphere," TRW Internal Publication.

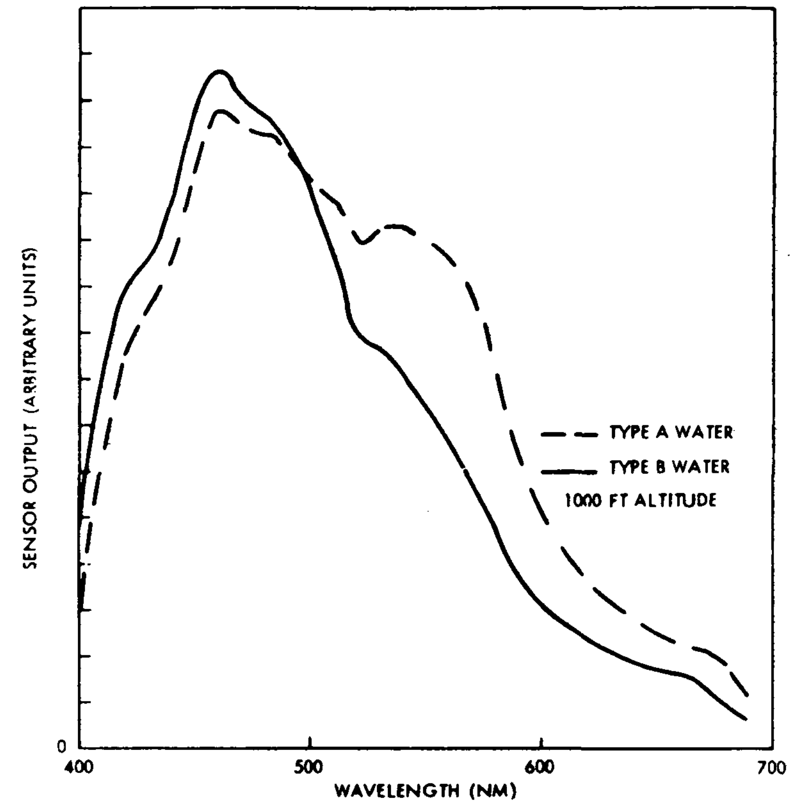

FIGURE 1. UNREDUCED SENSOR OUTPUT SIGNAL - 1000 FT ALTITUDE

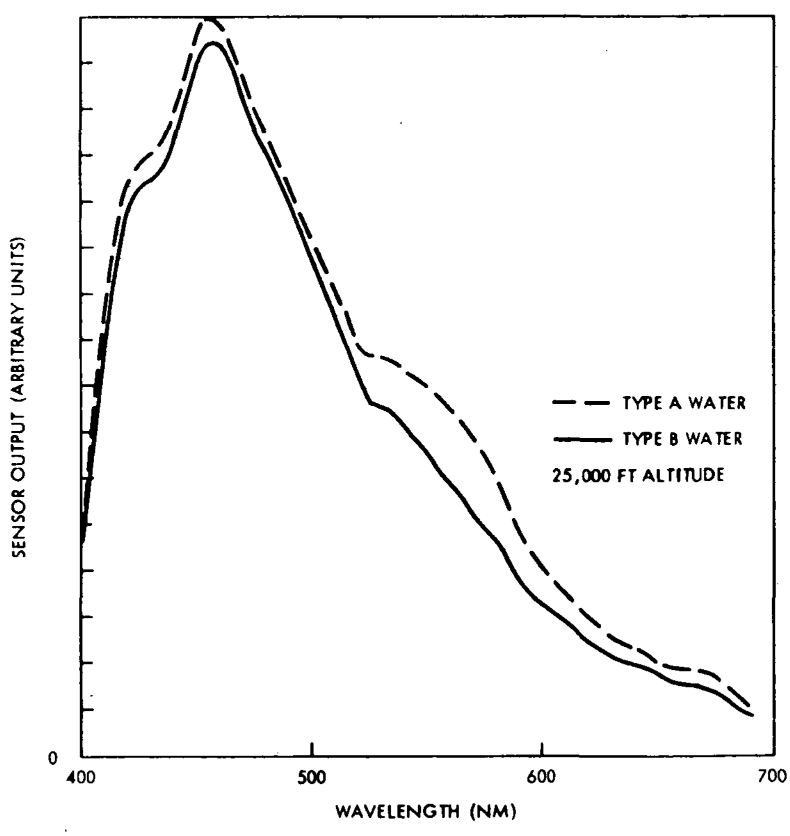

FIGURE 2. UNREDUCED SENSOR OUTPUT SIGNAL - 25,000 FT ALTITUDE

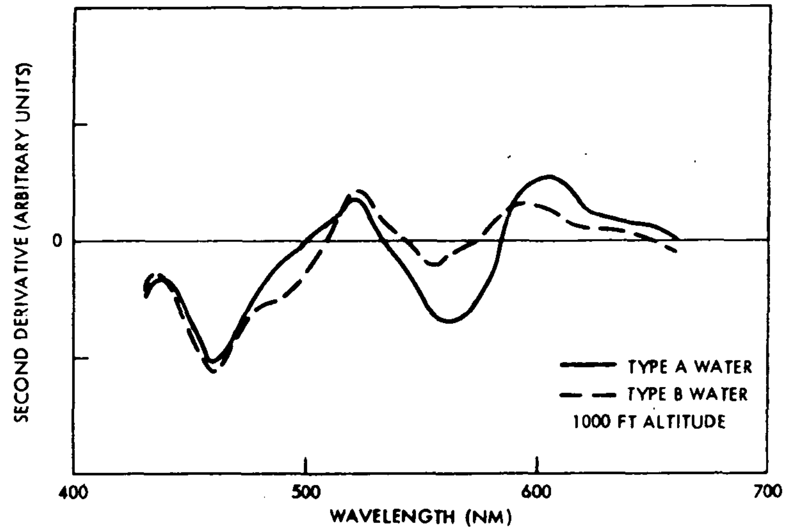

FIGURE 3. SECOND DERIVATIVES - 1000 FT ALTITUDE

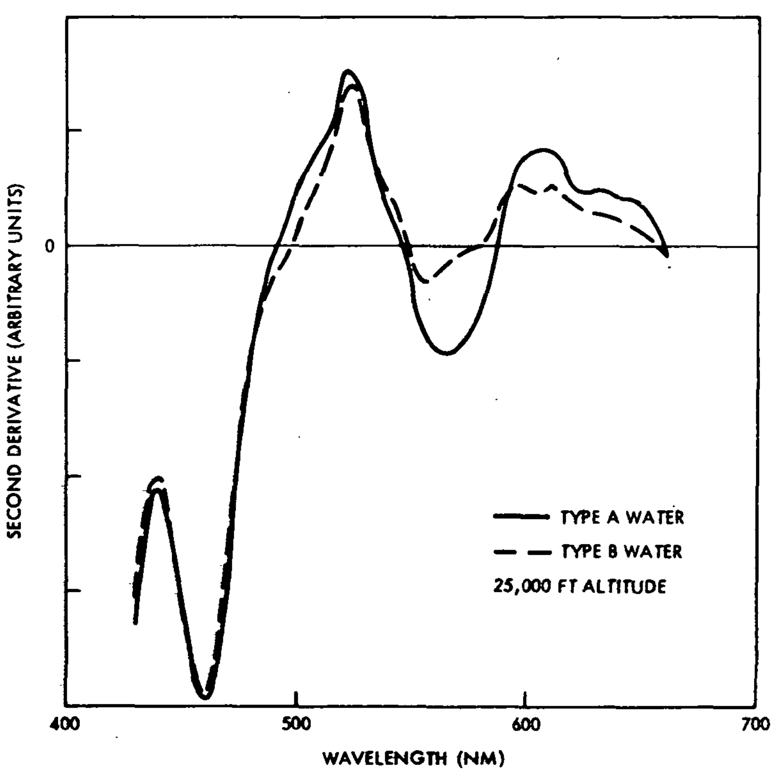

FIGURE 4. SECOND DERIVATIVES - 25,000 FT ALTITUDE

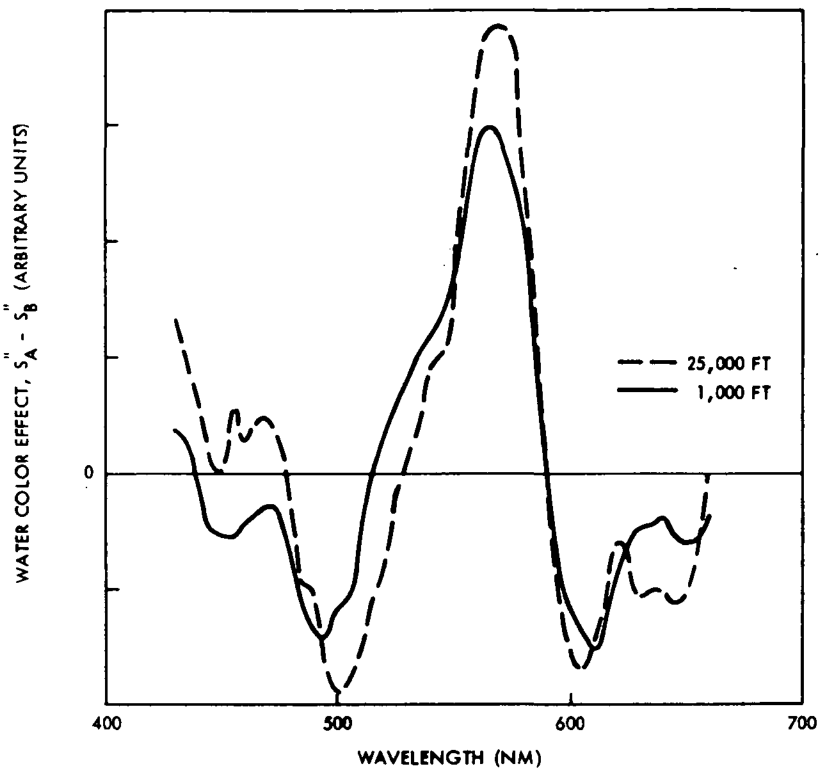

FIGURE 5. WATERCOLOR EFFECT ON SECOND DERIVATIVE

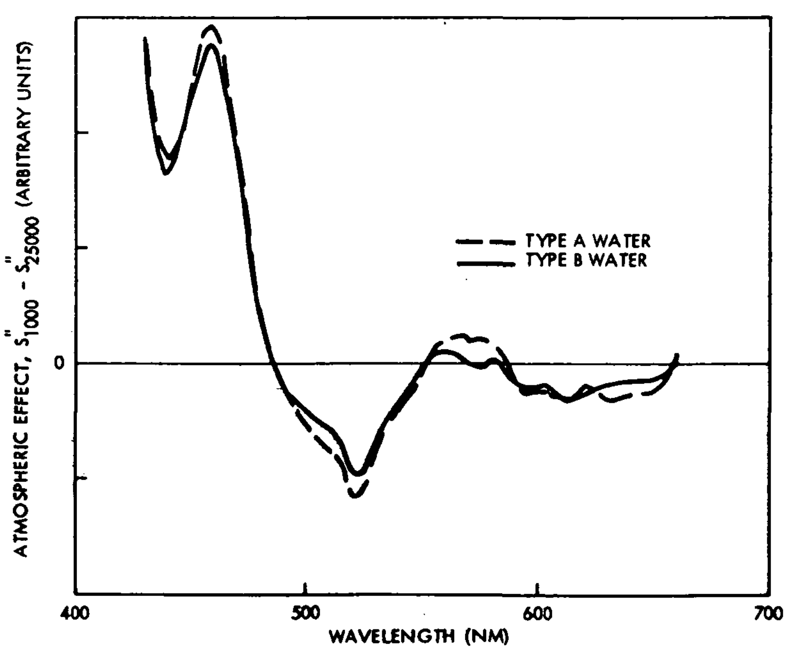

FIGURE 6. ATMOSPHERIC EFFECT ON SECOND DERIVATIVE

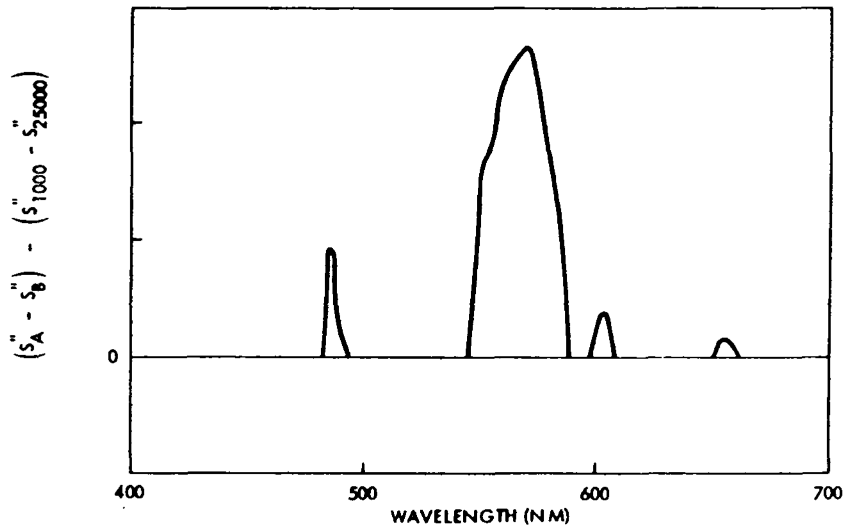

FIGURE 7. SPECTRAL REGIONS WHERE WATERCOLOR EFFECTS PREDOMINATE OVER ATMOSPHERIC EFFECTS

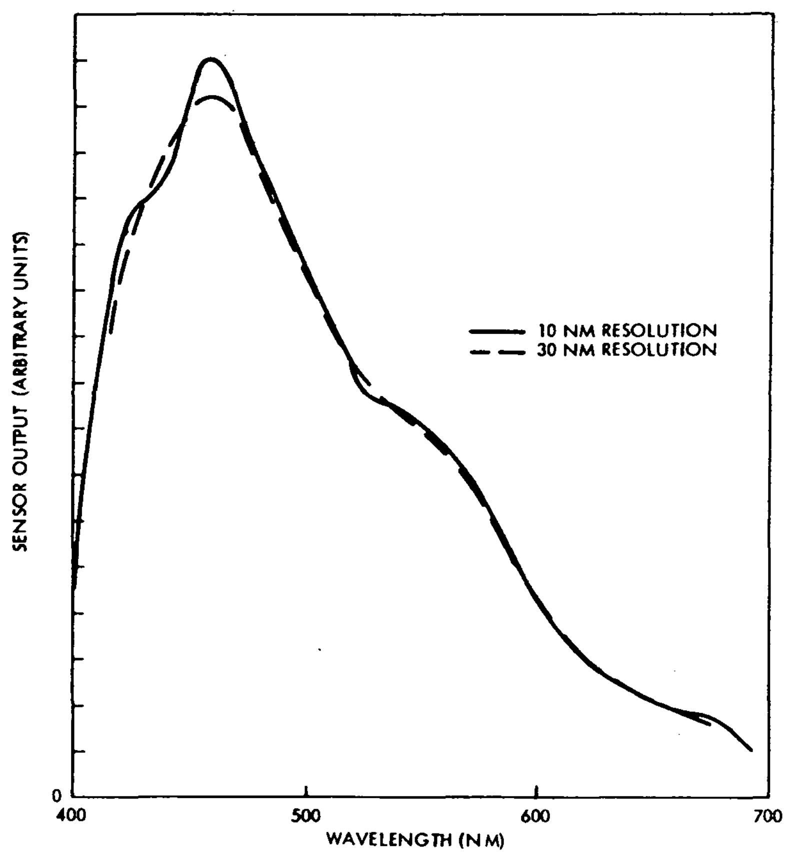

FIGURE 8. EFFECT OF SENSOR SPECTRAL RESOLUTION ON RAW DATA

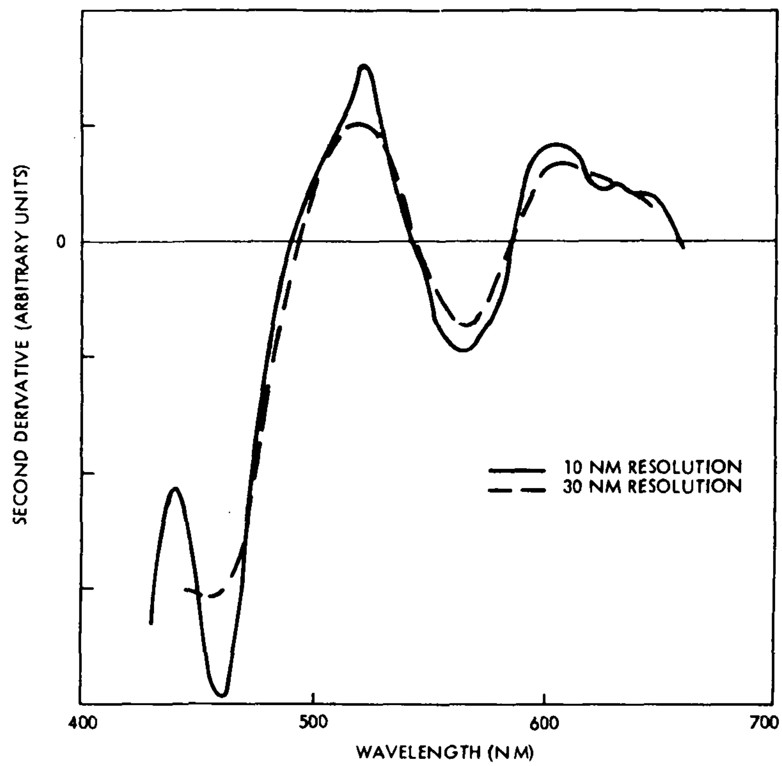

FIGURE 9. EFFECT OF SENSOR SPECTRAL RESOLUTION ON SECOND DERIVATIVE

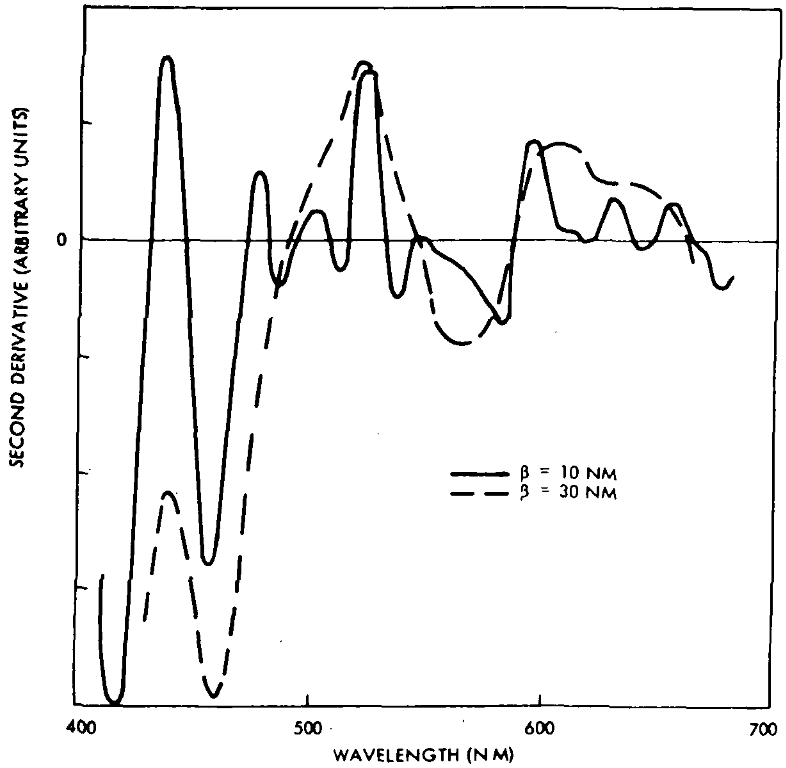

FIGURE 10. EFFECT OF FILTER PARAMETER β ON SECOND DERIVATIVE

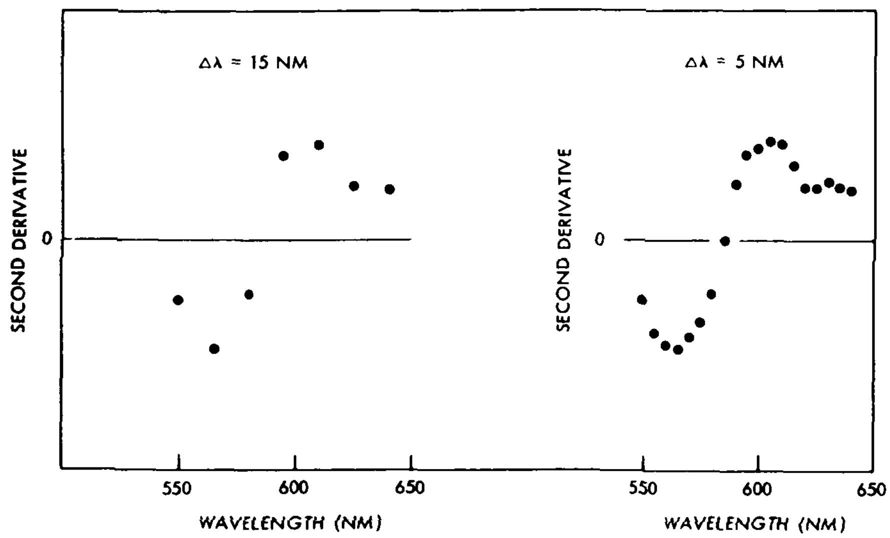

FIGURE 11. EFFECT OF SAMPLING RATE ON SECOND DERIVATIVE CURVE

APPENDIX G

RATIONALE FOR SELECTION OF A 2 PM DESCENDING ORBIT

1. INTRODUCTION

Figure 1 depicts the EOS spacecraft in orbit relative to the position of the glitter pattern reflected off a non-smooth ocean surface. This section develops the criteria for selection of an orbit for the EOS satellite that places the sensor field of view and the subsatellite trace in an acceptable orientation so that the glitter radiance does not destroy the apparent contrast of a selected target in the visible portion of the electromagnetic spectrum. The selected target is an extended area of chlorophyll with a concentration of 0.300 mg/M^3 contrasted against chlorophyll free ocean water. Scripps Institution of Oceanography* at San Diego has supplied apparent orbital contrast data as a function of viewing angle and sun zenith angle for two spectral bands (green and blue). Comparison of this data with consideration of sensor noise equivalent sensitivity allows determination of acceptable sun zenith angles of approximately 30 degrees to 65 degrees on hazy days and approximately 20 degrees to 75 degrees on clear days. These values assume that the sensor is pointed at nadir and has a 40 degree field of view — the required field of view for complete global coverage using a four day orbit.

Lower sun zenith angles are possible if the sensor is pointed off track from the subsatellite point in the direction away from the sun. If the sensor, for example is pointed 20 degrees off track away from the sun, then successful sun zenith angles are approximately 25 degrees to 65 degrees on hazy days and 15 degrees to 75 degrees on a clear day.

Previous analysis of information needs for the EOS ocean-dedicated satellite shows a requirement for a four-day coverage frequency. Several sun-synchronous orbits were examined to determine the number of days throughout the year that the sensor would be looking at acceptable sun

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* Unpublished data furnished by Dr. S. Q. Duntley of Scripps Institute for aid in selecting EOS orbital parameters.

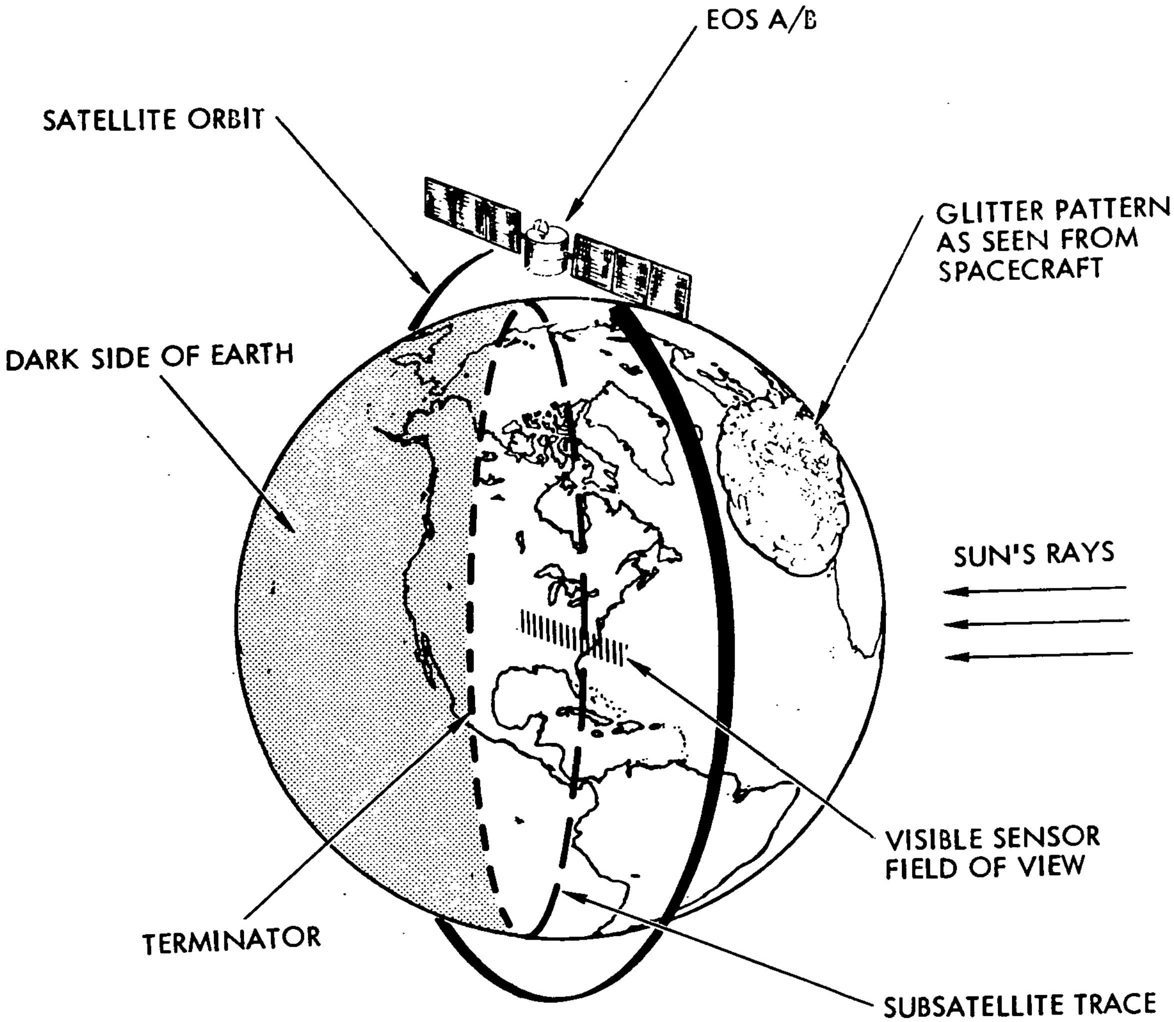


Figure 1. Sun, Earth, Orbit and Glitter Pattern Geometry

zenith angles. The first three orbits examined were those which passed the equator at 10:00 am, 10:40 am, and 11:20 am. Plots of sun angle variation as a function of days from vernal equinox were used to determine which latitude on the earth would have desirable sun zenith angles for 100 percent of the time and for 50 percent of the time. Results showed that the 10 am orbit gave the best overall coverage. Orbits earlier than 10 am were not considered because for much of the orbit the sun would be too low in the sky to provide sufficient illumination for good sensitivity. In addition, orbits earlier than 10 am would be passing coastal areas which would have predominantly been covered by morning fog for much of the year.

Finally the 2 pm orbit was considered; its earth geometry is somewhat like the 10 am orbit. In addition, all of the first cases were descending orbits; therefore, we investigated both the descending and ascending orbits for both 10 am and 2 pm geometries. Results showed that the 2 pm sun orbit gave broader coverage in the equatorial region than the 10 am orbit for those areas that were covered 100 percent of the time. In addition, the descending node favored the northern hemisphere. The final orbit selection, therefore, was a 2 pm descending orbit with the sensor field of view pointed 20 degrees off nadir away from the sun.

2. ORBITAL CONTRAST AND SENSOR SENSITIVITY

Figure 2 is an example of the data obtained from Scripps. Shown in the figure are polar plots of apparent orbital contrast as a function of angle of view from the nadir. The center of the diagram represents the contrast value for looking straight down below the spacecraft. As one looks toward the sun (looking upwards in the diagram), contrast values are reduced due to sun glitter. Likewise, looking away from the sun contrast values are improved. The data was obtained by making measurements from an aircraft for a range of sun-zenith angles and the range of wind speeds from 10 knots to 14 knots. Data was obtained on both clear days and hazy days. All of the aircraft data was taken over water assumed free of chlorophyll. When this data is plotted it represents purely the affects of sun glitter and surface reflection. Then, a representative culture that contained 0.3 mg per cubic meter of chorophyll was analyzed for scattering and reflection properties. This information was then computerized and analytically added to the aircraft data to represent the apparent contrast that the sensor would see if it could compare chlorophyll free water with the above concentration of chlorophyll water.

The data from Scripps was provided for two different color bands. Figure 3 shows the blue and green band pass filters that Scripps used for the aircraft data collection and the orbital contrast value analyses. Given the apparent orbital contrast data and the filter band-pass information we know its field of view and its noise equivalent sensitivity as a function of spectral wave lengths may be determined. Figure 4 is a plot of sensor noise equivalent sensitivity as a function of wavelengths for a current state

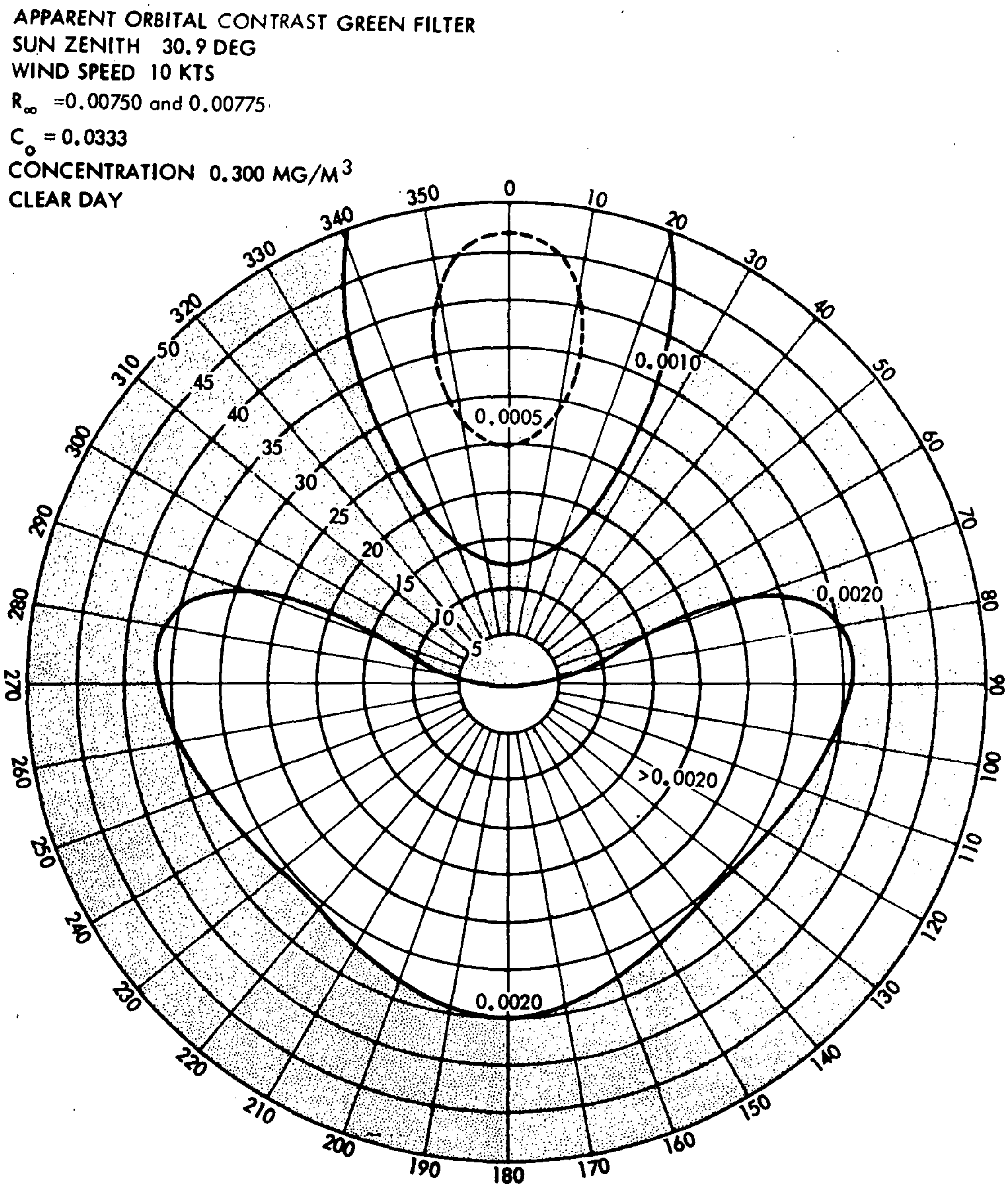
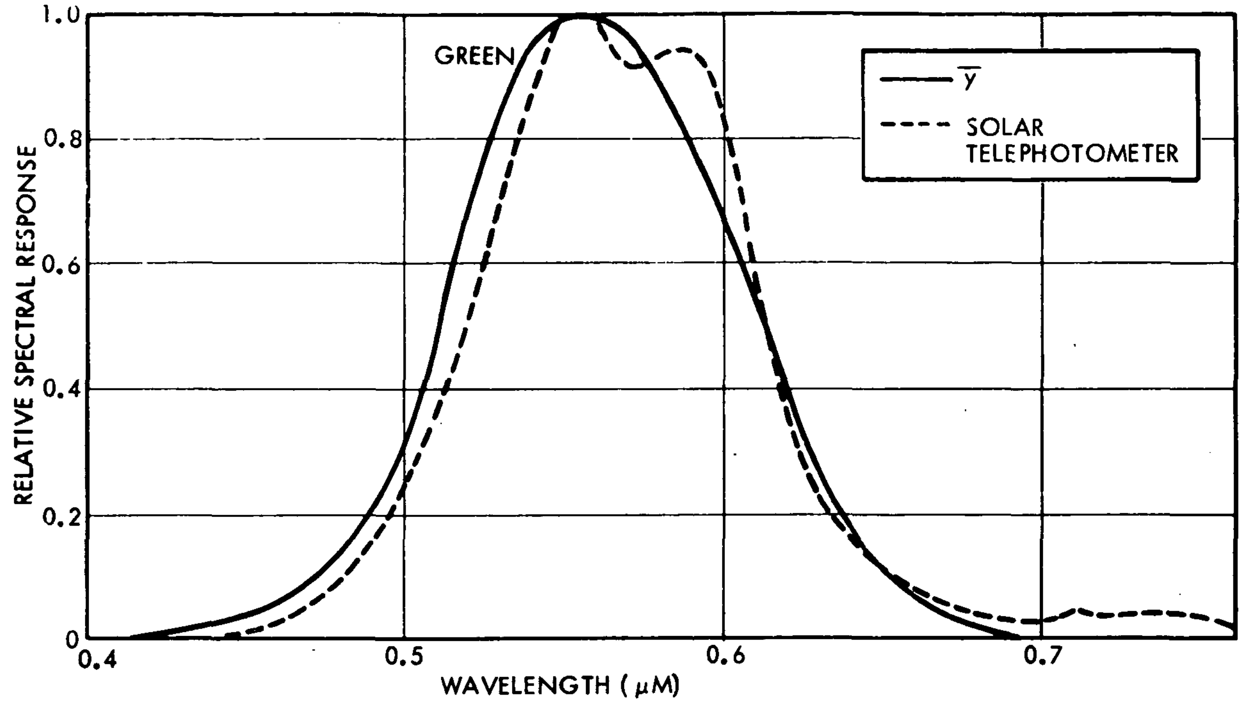


Figure 2. Example of Scripps Polar Contrast Plots

of the art imaging spectroradiometer. Calculations of the spectroradiometer performance assumed a moderately clear atmosphere. Additional data acquired from TRW's ocean color spectrophotometer flights show that an increase in noise equivalent sensitivity of about 40 percent is required for hazy day conditions.



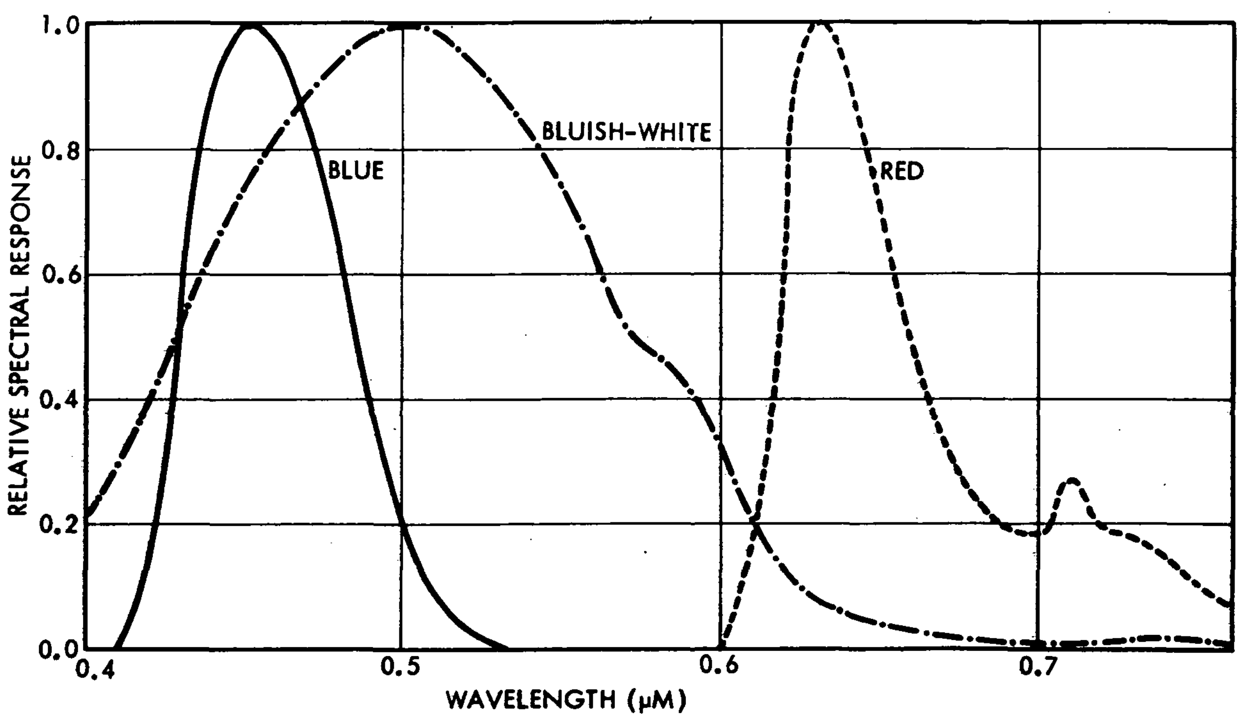


Figure 3. Green and Blue Filters Used for Collection of Scripps Data

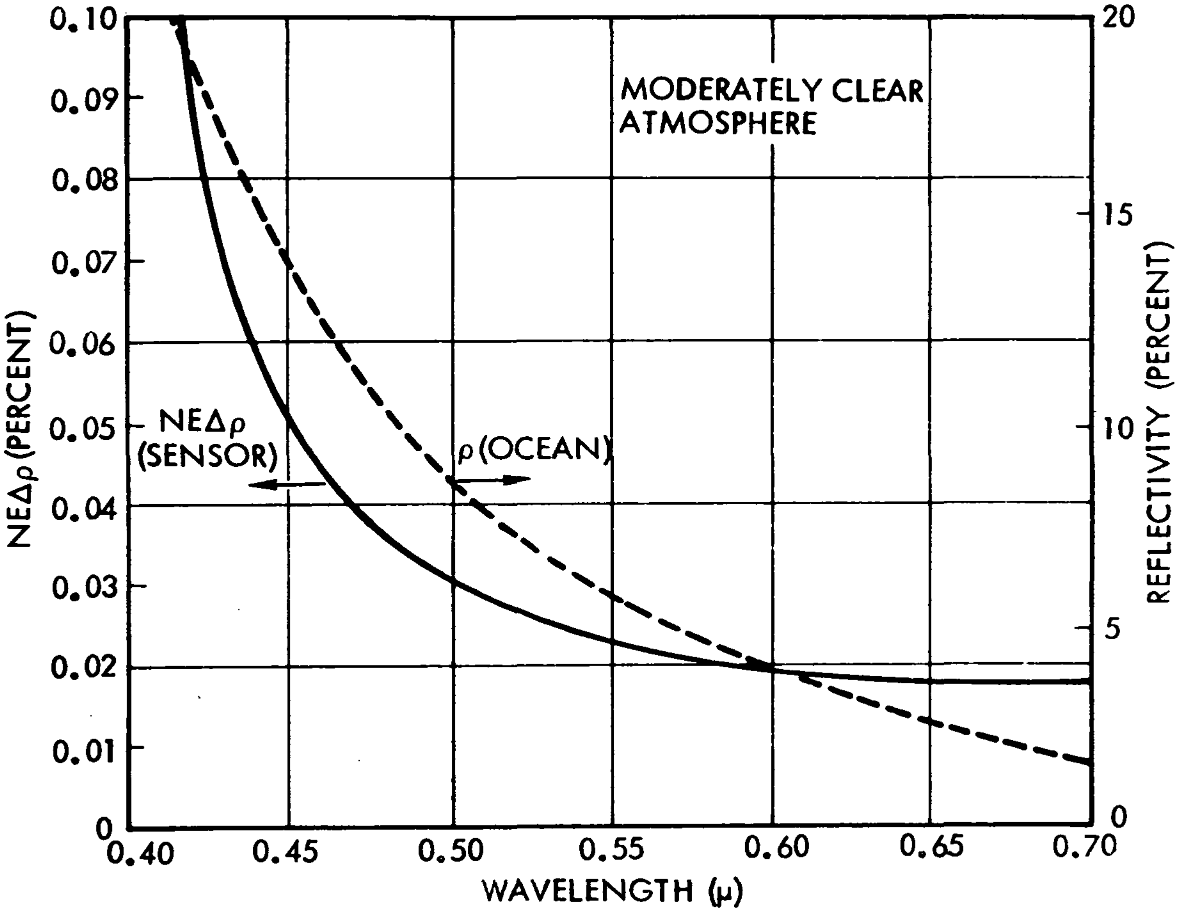


Figure 4. Sensor Sensitivity

As mentioned above, the data shown in Figure 2 was an example of one case of contrast data provided by Scripps. That case was the clear day using a clear filter with a sun zenith angle of 30.9 degrees. Other cases included data using blue and green filters, data obtained on clear and hazy days, and data acquired for sun zenith angles from 24.5 degrees to 70.6 degrees in sun zenith angles.

A comparison of sensor sentivities with the Scripps apparent contrast data as a function of view angle from nadir is shown in Figure 5. The top two plots compare hazy day results with clear day results for the green filter. The bottom two plots compare hazy day and clear day results using equivalent sensitivity (NEΔρ). In each figure the contrast values are plotted as a function of the look angles in degrees from nadir. Negative look angles represent viewing towards the sun's reflection and positive values represent looking away from the sun's reflection. Data was plotted for degrees to +40 degrees for two reasons. First, worldwide coverage using the four-day synchronous orbit requires the field of view of ± 20 degrees.

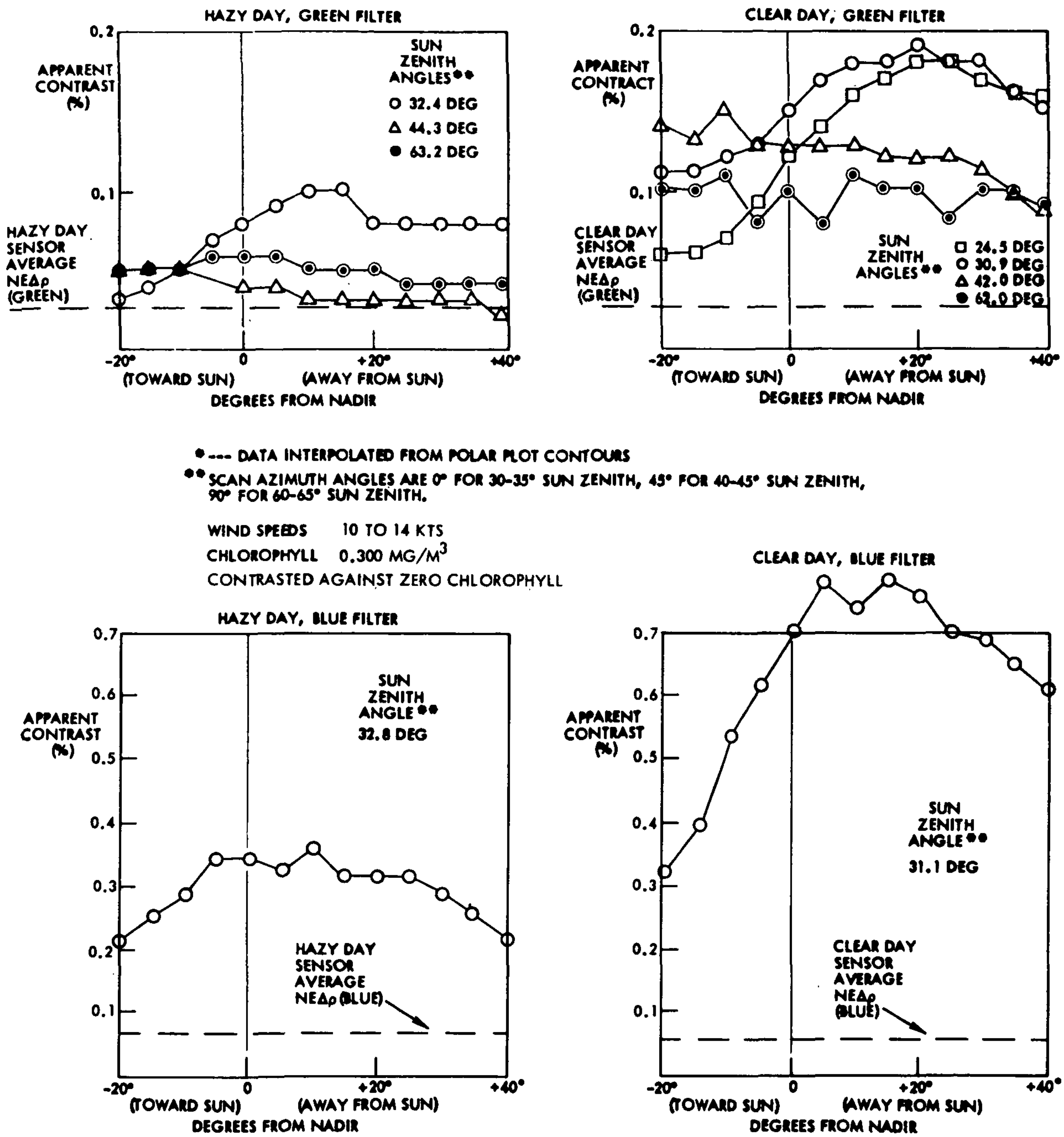


Figure 5. Contrast Versus View Angle from Nadir Compared With Sensor Sensitivity

Secondly, data was plotted to + 40 degrees since we are interested in the possibility of pointing the sensor off nadir away from the sun. Values for NE$\Delta\rho$ represented by the dotted line were obtained by comparing the band pass filters in Figure 3 with the sensor performance curve shown in Figure 4.

An average value over that bandpass was assumed. Since data processing of spectral data will involve correlation algorithms over several spectral bands, we will assume that contrast values equal to or greater than NE$\Delta\rho$ will be acceptable for the worst case bandpass. Each curve in Figure 5 represents a different sun zenith angle. It is assumed that the sensor will be of a line-scanning spectrophotometer This means that the field of view will essentially be a straight line slit. ranging from -20 to +20 degrees. It is assumed that the orbit will be of a 10 to 11:20 o'clock or 12:40 o'clock sun synchronous orbit since these orbits will allow a high enough sun-zenith angle to provide sufficient illumination for a good signal yet not so high that data would be destroyed by the sun glitter pattern as we cross near the equator. For these ranges of orbits the sun zenith angle experienced by the sensor as the satellite passes over the equator will be in the 25 to 35 degree range. This means that for the lower sun zenith angles around 30 degrees shown in Figure 5, the sun will be in the plane of the sensor field of view. Therefore, the data was plotted from the Scripps polar plots assuming that the sun would be in the sensor plane field of view. However, when the sensor will be seeing the higher sun zenith angles around 60 degrees, the satellite must be in the northern latitudes and therefore the sun will more nearly on a line perpendicular to the sensor line field of view. Therefore, for the higher sun zenith angles in Figure 5, the data was plotted from the Scripps polar plots on a line of 90 degrees azimuth relative to the sun. Finally for intermediate sun-zenith angles around 45 degrees, a 45 degree azimuth plot was used. This means that when the satellite is in the intermediate latitudes and the angle between the sensor field of view line and the line between the glitter pattern and center sensor field of view center will be approximately 45 degrees.

Results show that the worst case is looking down through a hazy atmosphere with a green filter. For both the green and blue filter, conditions are greatly improved on clear days. It appears that the range of allowable sun zenith angles when viewing on a clear day is significantly greater than viewing on a hazy day. In addition, for each of the four cases in Figure 5, contrast is greatly improved by looking away from the sun at low sun zenith angles, i.e., at low latitudes. Therefore, a determination of acceptable sun zenith angles should include a comparison between hazy day and clear days and a comparison between pointing the sensor straight down below the spacecraft and pointing the sensor 20 degrees off track away from the sun.

3. ACCEPTABLE SUN ZENITH ANGLES FOR CHLOROPHYLL CONTRAST DETECTION

The next task was to examine the data shown in Figure 5 to derive the upper and lower limits of acceptable sun zenith angles. To determine the upper limit, apparent contrast data from Figure 5 is plotted in Figure 6 as a function of sun zenith angle. Only the hazy day and clear day green filter data is plotted from Figure 5 since these represented the worst case with respect to signal and noise. Each curve in Figure 6 represents a different view angle and since we are considering both sensor nadir pointing and sensor off nadir pointing, all extreme values of possible viewing are

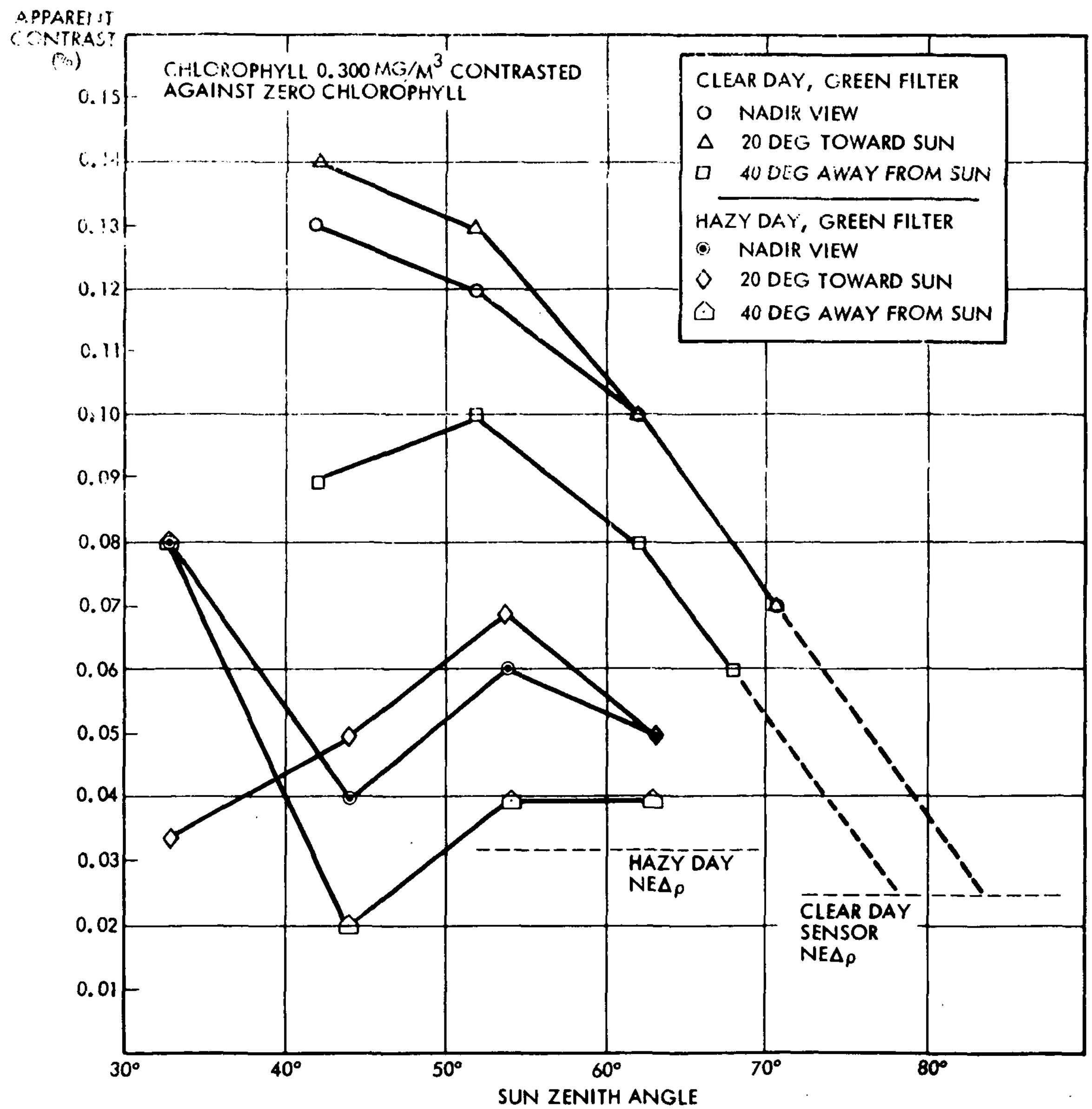


Figure 6. Extrapolation of Apparent Contrast Toward Higher Sun Zenith Angles

included. As mentioned previously, when the satellite is in the high latitudes or at high sun zenith angle viewing the line between the center of the sun glitter pattern and the center of the sensor field of view is nearly perpendicular to the sensor slit field of view. This means that the affect due to sun glitter will be nearly uniform over the field of view so that apparent contrast values across the sensor field of view will not vary greatly in the high latitudes. Results in Figure 6 show that for clear day conditions there is a definite trend in the data and that an extrapolation is possible toward a limiting sun zenith angle. Examining the clear day curves it is concluded that a conservative estimate for an upper limit for sun zenith angle would be 75 degrees for a clear day. On the other hand, the hazy day data does not show a definite trend. Therefore, an upper limit of 65 degrees is selected since at this time we do not have sufficient data to extrapolate to any higher value. In either case, Figure 6 shows that the limiting contrast values are well above the sensor NE$\Delta\rho$ values for both hazy day and clear day conditions.

With respect to the lower limit on sun zenith angles, Figure 7 shows the relationship between contrast values and low sun zenith angles for three viewing angles - the nadir view, 10 degrees off nadir towards the sun and 20 degrees off nadir towards the sun. Since there are insufficient hazy day data to show a definite trend, only the clear day data for the green filter from Figure 5 is shown. In addition the sensor NE$\Delta\rho$ for the green filter and for a clear day is sketched in the figure to aid in determining the lower limit value of sun zenith angles. If the sensor is pointed straight down toward nadir and has a 40 degree field of view then the worst case sun glitter in that field of view would be the 20 degree toward the sun view angle curve. In addition a curve for 10 degrees toward the sun was included as supporting evidence that the trend (slope) shown in the 20 degree curve is valid. Comparing the NE$\Delta\rho$ value with the 20 degree curve results in an optimistic estimate of 20 degrees for the lower limit of acceptable sun zenith angles for the sensor pointed straight down on a clear day using the green filter. Since Figure 5 shows that the blue filter data is always much better with respect to signal to noise that the green filter we will assume that this is the limiting value for a blue/green multispectral sensor.

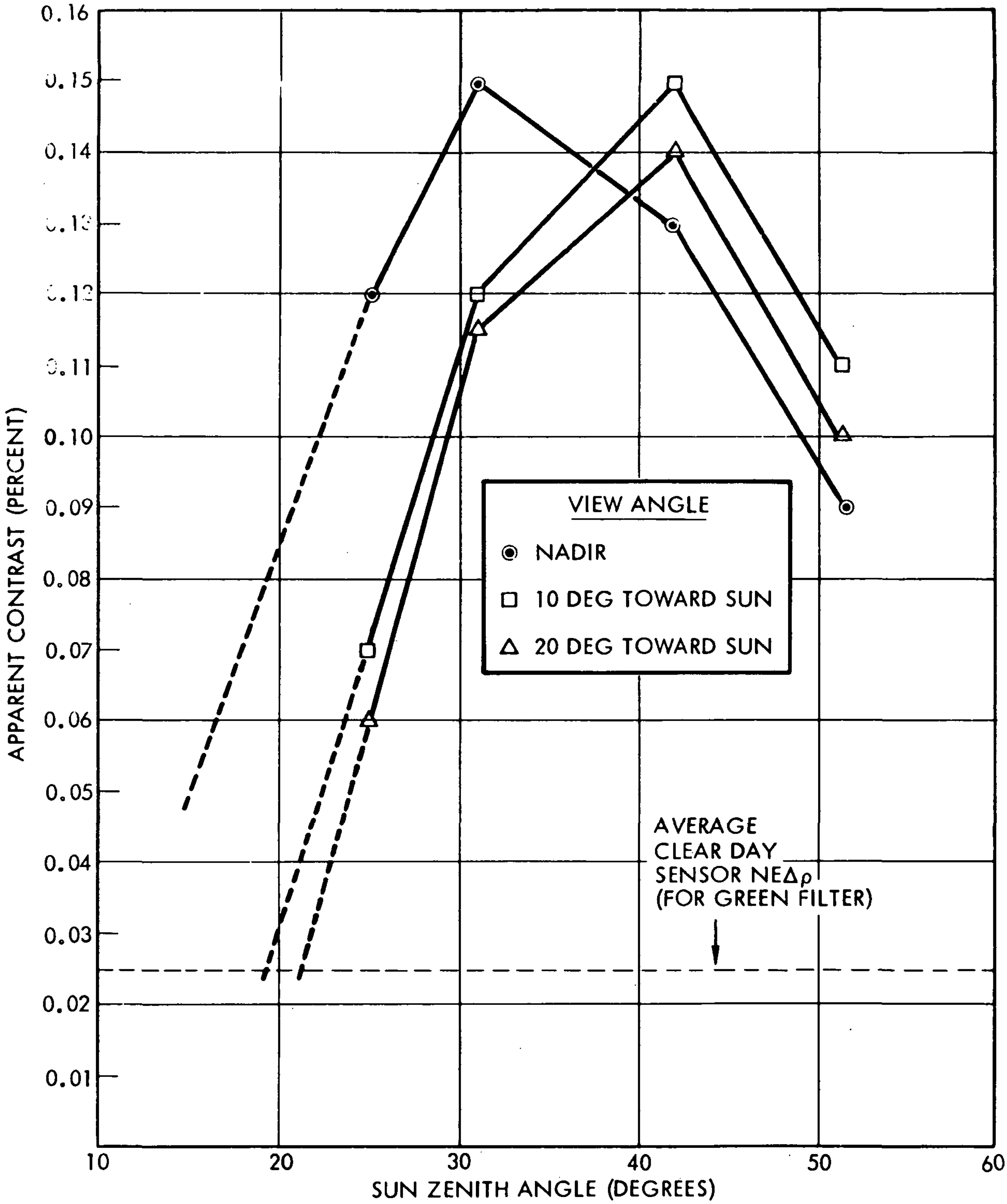


Figure 7. Extrapolation of Apparent Contrast Toward Low Sun Zenith Angles (Clear Day, Green Filter Data)

If the 40 degree field of view sensor is pointed 20 degrees off nadir away from the sun then the worst case view angle in the sensor field of view with respect to sun glitter would be that edge of the field of view nearest the sun which would be viewing nadir. Examining the curve in Figure 7 for the nadir view angle, and assuming the same trend as provided by the 10 degree and 20 degree view angle curves, one could conservatively estimate that the lower limit for sun zenith angle with a sensor pointed 20 degrees off nadir would be approximately 15 degrees. This again is for clear day conditions. Thus, pointing the sensor away from the sun off nadir by 20 degrees improves the lower limit of acceptable sun zenith angles by 5 degrees in going from 20 degrees to 15 degrees.

With respect to lower limits on sun zenith angle for hazy day conditions, the hazy day green filter data in Figure 5 gives a limiting case of 32.4 degrees for a sensor pointed straight down at nadir since the 20 degrees towards the sun would be the worst case for sun glitter. Thus, a value of approximately 30 degrees for hazy day viewing conditions is assumed. Since a 5 degree improvement is allowed in clear day conditions by pointing off nadir away from the sun, it is assumed that during hazy day conditions the same 5 degree improvement is possible. Therefore, a lower limit of 25 degrees is assumed for sun zenith angle if the sensor is pointed 20 degrees off track away from the sun during hazy day conditions.

A summary of the above discussion is shown in Table 1 where the acceptable sun zenith angle range is listed for each atmospheric condition and for each sensor pointing condition.

Table 1. Summary of Acceptable Sun Zenith Angles

VIEWING CONDITIONS (40 DEG FOV)			SUN ANGLE RANGE* (DEG.)
HAZY DAY	-	LOOKING STRAIGHT DOWN	30 TO 65
HAZY DAY	-	LOOKING 20 DEG OFF TRACK AWAY FROM SUN	25 TO 65
CLEAR DAY	-	LOOKING STRAIGHT DOWN	20 TO 75
CLEAR DAY	-	LOOKING 20 DEG OFF TRACK AWAY FROM SUN	15 TO 75

*FOR $NE\Delta\rho = 0.00025$ CLEAR DAY — GREEN

4. ORBIT SELECTION FOR MAXIMUM WORLD COVERAGE WITH RESPECT TO CHLOROPHYLL DETECTION

4.1 SUMMARY

This section first compares world chlorophyll detection coverage for three orbit cases - the 10 am, 10:40 am and 11:20 am orbits. For each orbit case four viewing conditions are analyzed. These are hazy day conditions looking straight down at nadir; hazy day conditions with the sensor pointing 20 degrees off track from nadir; clear day conditions with the sensor pointing straight down and clear day conditions with the sensor pointed 20 degrees off track away from the sun.

4.2 DISCUSSION

In forming the above decisions it was first determined what percent of the year chlorophyll detection would be possible as a function of latitude given the acceptable sun zenith angle ranges derived in the previous section. (By chlorophyll detection we are still assuming a contrast between chlorophyll free water and water with a chlorophyll concentration of 0.3 milligrams per cubic meter.) Figure 8 shows the variation of sun zenith angle against the days from vernal equinox for the northern hemisphere and for the 10 am descending orbit. Similar curves were examined that cover all of the orbit geometries considered for both northern and southern hemisphere cases. Figure 8 is included here as an illustrative example. Using the sun zenith angle limits shown in Table 1 it is possible to determine from curves such as Figure 8 which portion of the globe chlorophyll may be detected for 100 percent of the year and which portions of the globe chlorophyll may be detected for at least 50 percent of the year. Figure 9 compares results of these determinations for the 10 am, 10:40 am and 11:20 am descending orbits. As previously mentioned, four different combinations of atmospheric conditions and sensor pointing conditions are included for each orbit. In many cases there are equatorial regions of the glove in which even 50 percent of the year coverage is not possible since the sun zenith angle falls into the acceptable ranges for less than half of the year. For those latitude regions, exact calculation of the percent of the year during which coverage is possible is presented for every 10 degrees of latitude. Results in Figure 9 show that only the 10 am orbit gives equatorial coverage for at least 50 percent of the year during hazy

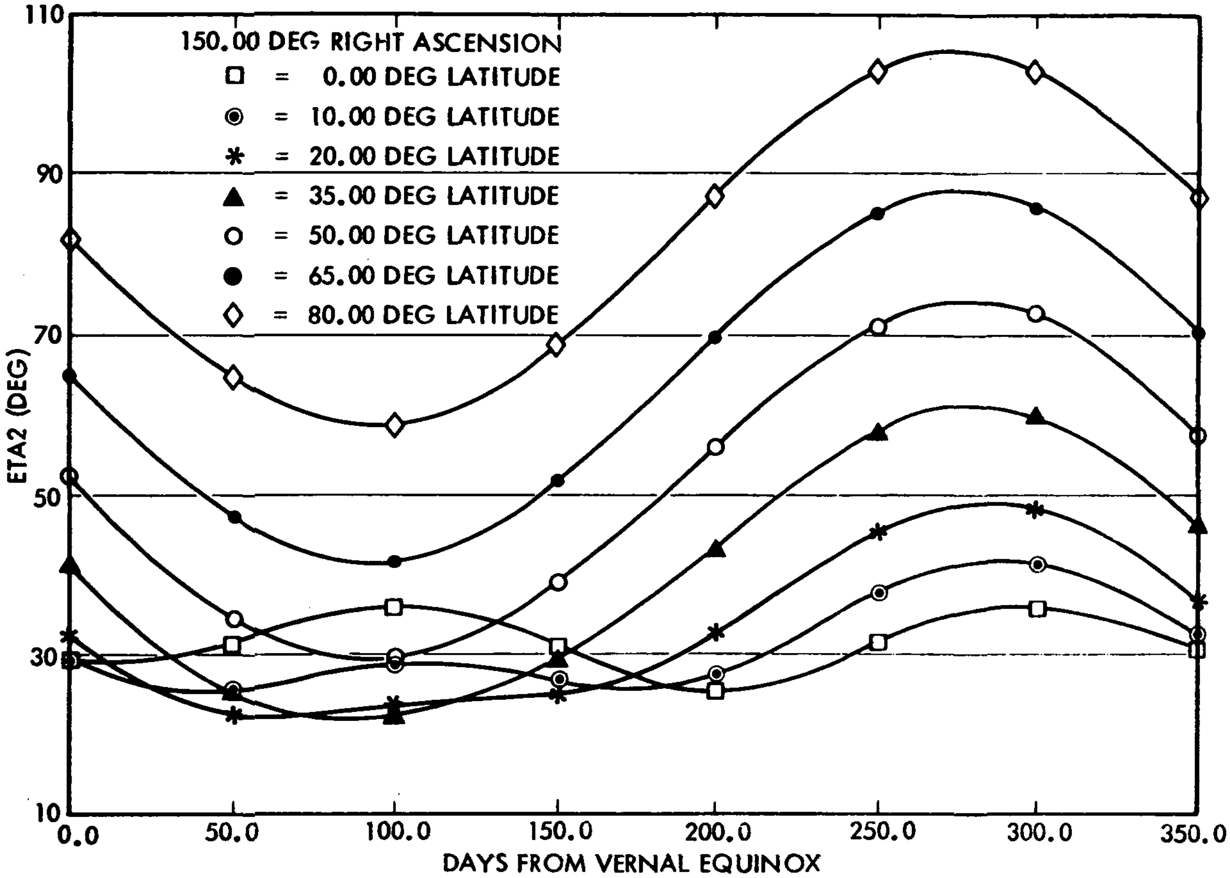


Figure 8. Sun Angle Variation Versus Days from Vernal Equinox

day conditions provided the sensor is pointed 20 degrees off track away the sun. In addition, any sacrifice made in high latitude coverage by selecting the 10 am orbit over the other two seems to occur mainly in the southern hemisphere. For these reasons, the 10 am orbit geometry with an off-pointing sensor is the initial selection.

Utilizing the same methods employed in Figure 9, a comparison between ascending and descending orbits and 10 am and 2 pm geometries is provided in Figure 10. Since the off-pointing sensor orientation has already been selected, comparison for each orbit is only made between hazy day and clear day conditions. Inspection of Figure 10 shows that the 2 pm orbit provides better hazy day coverage than the 10 am orbit. This result depends upon the fact that hazy day sun zenith angle range is a smaller range than the clear day range and has critical effects upon small changes in the sun angle variation curve as shown in Figure 8. Otherwise stated, the

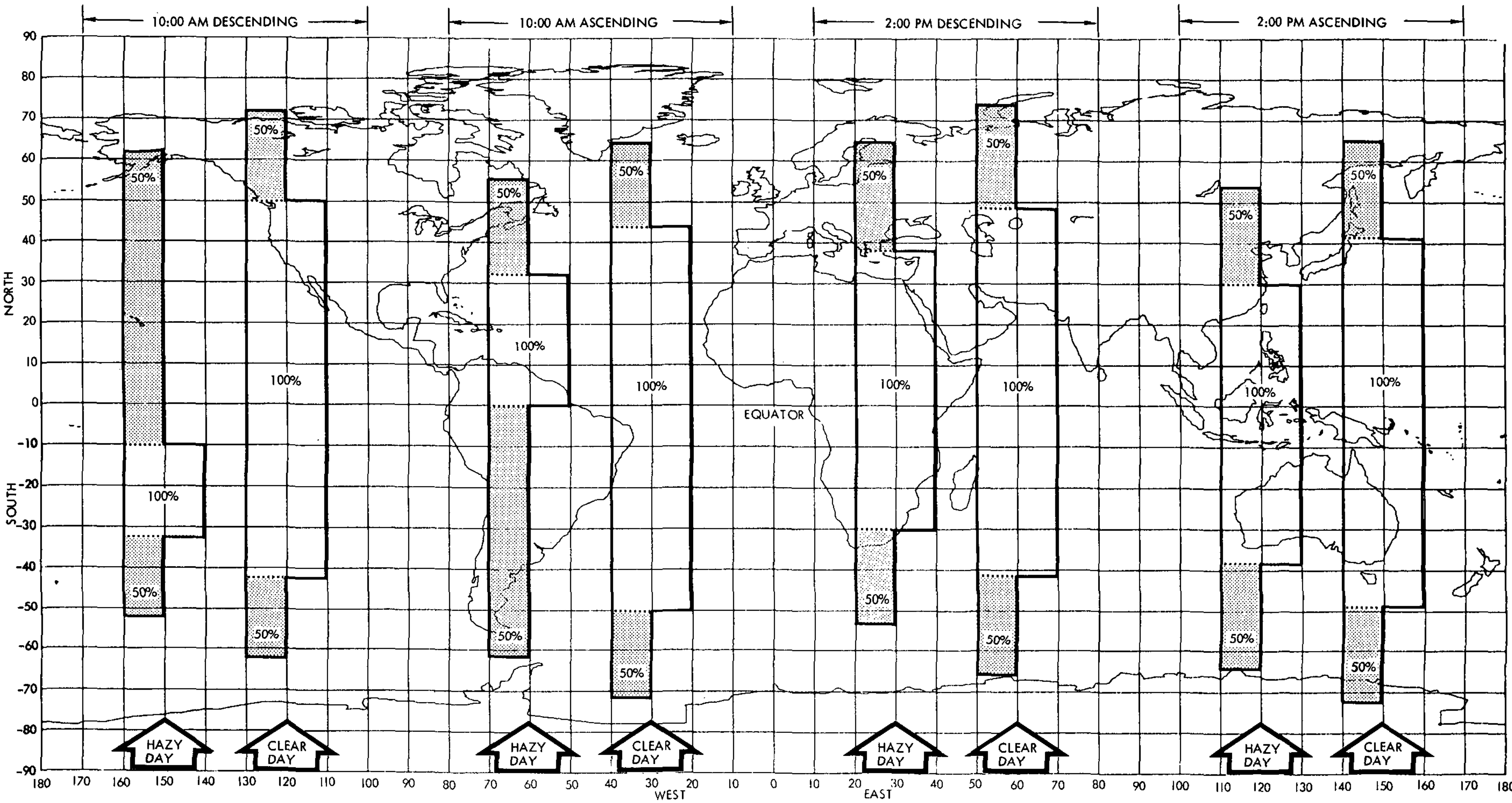


Figure 9. EOS World Coverage for Chlorophyll Detection in Terms of Percent of Year that Sensors can Detect 0.300 MG/M^3 Contrasted Against Chlorophyll Free Water

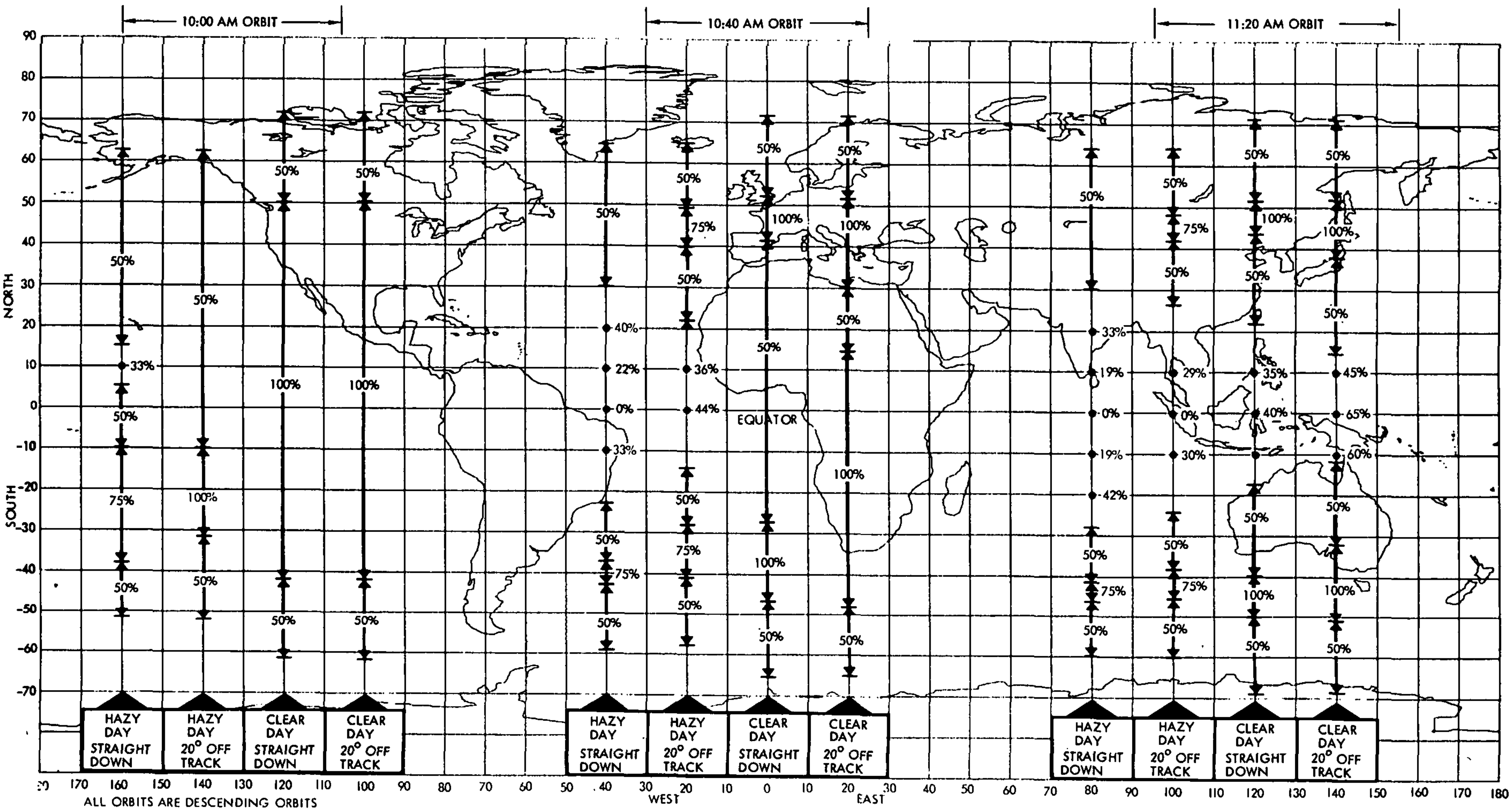


Figure 10. Chlorophyll Coverage for 10 am and 2 pm Orbits - 0.300 MG/M^3 Chlorophyll Contrasted Against 0 Chlorophyll Sensor Field of View Pointed 20 Degrees Off Nadir Away From Sun

10 am orbit cannot provide 100 percent equatorial coverage in both the northern and southern hemisphere during hazy days because the sun angle variation curves such as those shown in Figure 8 are asymmetrical in the equatorial region and have various anomalies which result in asymmetrical latitude coverage in a critical sun zenith angle range is employed. However for the 2 pm orbits these anomalies appear to be less critical and 100 percent equatorial coverage is possible for the hazy day narrow sun zenith angle range. Therefore, the 2 pm orbits seem the most desirable. One may question that afternoon wind speeds may cause rough waters that will limit the remote sensing task, but the initial data provided by Scripps was for sea state conditions resulting from 10 to 14 knot winds. Therefore, the 2 pm coverage would still seem feasible even wind speed considerations for sea state conditions resulting from 10 to 14 knot winds. Therefore, the 2 pm coverage appears feasible. In addition, with respect to coastal morning haze and fog, the 2 pm orbit seems more desirable since often hazy conditions are cleared up by afternoon. Furthermore, a comparison between the descending and ascending orbits for 2 pm show that the descending orbits favor the northern hemisphere and continental U. S. coverage would be further enhanced by selecting the descending case. Final orbit selection is therefore a 2 pm descending orbit for a 40 degree field of view multispectral sensor that is pointed 20 degrees off nadir away from the sun.

APPENDIX H. RELATIONSHIP TO OTHER SPACE PROGRAMS

In establishing the payload groupings of Section 3, other planned and existing space programs were examined. As shown in Table H-1, Nimbus E appears to be a reasonable candidate for global oceanography in the infrared spectral region. (The temperature-humidity infrared radiometer has a resolution of 4.2 nmi.) On the other hand, there are no visible sensors (ocean color or glitter), altimeters or synthetic aperture radar in its payload. The microwave sensors do not meet requirements. Nimbus F also has reasonable requirements in the infrared region, but does not have any visible sensors, altimeters or synthetic aperture radar or the required microwave. Again, in the infrared region Tiros N&O seem to have particularly good sensors with respect to global oceanography but this is only one spectral region and as a result it does not satisfy all the requirements of global oceanography. The two drawbacks of the remaining planned spacecraft in the EOS A/B time period, which includes the SMS-A, GOES I & II, SATS and ATS-F, -G, -H, are:

1) Poor resolutions incurred in a geosynchronous orbit, and
2) The focus on a specific region as opposed to obtaining complete global coverage.

SMS-A and GOES I&II will have a Data Collection System which should be adequate for the EOS mission except for the tracking of buoys.

Based on the spacecraft projected for the 1975-1976 time period shown in Table H-1, an EOS spacecraft dedicated to obtaining global oceanographic data as depicted in the main body of the report would have very little redundancy. The main duplication in data acquisition with the required resolution and accuracy would occur in the infrared spectral region (Tiros N&O and Nimbus E&F).

Table H-1. Projected Space Programs (1975-1976)

UNMANNED SPACECRAFT	PURPOSE	LAUNCH DATE	ALTITUDE APOGEE/PERIGEE KM	INCLINATION	PAYLOAD	COMMENTS
NIMBUS E	RESEARCH	5/72	600/600	SUN-SYNC.	TEMPERATURE-HUMIDITY INFRARED RADIOMETER SELECTIVE CHOPPER RADIOMETER SURFACE COMPOSITION MAPPING RADIOMETER ELECTRICALLY SCANNING MICROWAVE RADIOMETER REALTIME DATA RELAY INFRARED TEMP. PROFILE (MULTI-CHANNEL) RADIOMETER MICROWAVE SPECTROMETER	(18-36μ ABSORPTION BAND) RES. 7.8 KM NONIMAGING RES 0.6 KM RES 63 KM NONIMAGING NONIMAGING
NIMBUS F	RESEARCH	1/73	-	-	MAPPING MICROWAVE SPECTROMETER ELECTRICALLY SCANNING MICROWAVE RADIOMETER SOLAR COSMIC RAY & TAPPED PARTICLE HIGH RESOLUTION IR RADIATION SOUNDER TROPICAL WIND, ENERGY CONVERSION & REF. LEVEL PRESSURE MODULATED CO_2 RADIOMETER FOR UPPER ATMOSPHERE TEMPERATURE SOUNDING TEMPERATURE-HUMIDITY IR RADIOMETER EARTH RADIATION BUDGET LIMB RADIANCE INVERSION EXPERIMENT ELECTROSTATIC PROBE STUDIES POSITIVE ION COMPOSITION REAL-TIME DATA RELAY EXPERIMENT	 RES 63 KM N/A NONIMAGING NONIMAGING 15μ ABSORPTION BAND (18-36μ) ABSORPTION BAND 7.8 KM N/A N/A N/A N/A (GROUND/OCEAN PLATFORM TRANS. S/C)
ITOS, E,F,G	OPER.	72-75	1460/1460	SUN-SYNC.	SCANNING RADIOMETER VERY HIGH RESOLUTION RADIOMETER OMNIDIRECTIONAL RADIOMETER SOLAR PROTON MONITOR	VIS (.52 - .73μ) RES 3.7 KM IR (10.5-12.5μ) RES 7.4 KM POOR RES/LOCAL COVERAGE N/A MINOR CONTRIBUTION
TIROS N	RESEARCH/ OPER.	76	1662/1662	SUN-SYNC.	4-CHANNEL IMAGING RADIOMETER VERTICAL TEMP. SOUNDER DATA COLLECTION SYSTEM	SIGNIFICANT CONTRIBUTION TO OCEANOGRAPHIC APPLICATIONS (TRANS. FROM GROUND/OCEAN PLATFORMS)
TIROS-0	RESEARCH/ OPER.	75	1298/1298	SUN-SYNC.	HIGH RESOLUTION RADIOMETER SCANNING RADIOMETER VERTICAL TEMP. PROFILE RADIOMETER	SIMILAR TO TIROS N
SMS A	RESEARCH/ OPER.	7/72	35,600/35,600	GEO SYNC=>0°	DAY/NIGHT TELESCOPE AREA VIEWED 7000 SQ NMI RESOLUTION .9 KM VIS., 7.4 KM IR. DATA COLLECTION SYSTEM (SEE BELOW)	VISIBLE INFRARED SPIN SCAN RADIOMETER SPEC RES (10.5-12.6μ) SPAT RES .9 KM VIS., 7.4 KM IR POOR RES/ LOCAL COVERAGE
GOES 1-2	OPER.	74	35,600/35,600	0°	DATA COLLECTION SYSTEM (FOR COLLECTING AN RELAYING DATA FROM BUOYS, REMOTE GROUND PLATFORMS, SEISMIC STATIONS, ETC.) TELESCOPE/RADIOMETER RESOLUTION .9 KM VIS., 7.4 KM IR. 1/2 HR REVISIT TIME	POOR RES/ LOCAL COVERAGE
ATS F,G,H	RESEARCH	73-74	35,600/35,600	0°	COMM.-ANTENNA/TRANSMITTER PLUS OTHER APPLICATION SENSORS	POOR RES/ LOCAL COVERAGE
SATS	RESEARCH	74	35,600/35,600	0°	MICROWAVE RADIOMETER WIDE RANGE IMAGE SPECTROMETER RADIOMETRIC VERTICAL SENSOR COMPOSITE RADIOMETER-SPECTROMETER NANO-G ACCELEROMETER ALTIMETER DATA COLLECTION SYSTEM	 (TRANS. DATA FROM GROUND/OCEAN PLAT.)

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APPENDIX I. PRIORITY ANALYSIS

The first major element of the study was to define global ocean priorities, which are independent of the methods used to resolve the problems associated with the priorities, and which can be used to develop EOS oceanographic mission requirements. This appendix describes the process used in establishing priorities and their justification.

1. ESTABLISHING PRIORITIES

Individual and corporate needs in this country are interpreted by four principal institutions: government, industry, academia, and the general public. Each institution interprets its specific needs and within the limits of available resources and understanding, concentrates its efforts accordingly. The President, by nature of his office, exerts much more influence than any other single institution in establishing national and international priorities. This does not diminish the importance of priorities established by Congress, industry, academia, and individuals and groups within the public domain. Resulting programs and production of goods and services allows the fulfillment of selected needs.

In establishing relevant priorities, our ultimate aim was to elucidate global ocean priorities for the EOS program which meet the priorities of the principal institutions described above. Our approach in establishing relevant priorities is described as follows:

- Administration and Congressional Priorities

  Identify administration and congressional goals and the interpretation of those goals as they relate to global oceanography; review principal policy statements of federal executive offices and congressional committees to translate goals into stated (explicit) and inferred (implicit) relevant priorities; inventory and select principal government agencies who are the effectors of the administration and congressional priorities and determine relevant priority issues of principal agencies.

- Business Management Priorities

  Inventory private business groups and related organizations who are actively involved in management and use of the global ocean; review, screen, and classify these groups to select principal participants; identify and select relevant priority issues of importance to the principal participants.

- Research and Education Priorities

  Inventory academic and research groups actively involved in education concerning research in the global ocean; establish relevant education and research priority issues.

- Individual and Group Priorities

  Identify "conservation" groups related to global oceanographic problems; identify priority issues of concern to individual citizens and conservation groups; demonstrate the collective impact of the public on the global ocean.

1.1 ADMINISTRATION AND CONGRESSIONAL PRIORITIES

1.1.1 Explicit and Implicit Priorities

Many goals of the American people are clearly stated in the Constitution, while others are so firmly established in tradition they are taken for granted. Within the broad, generally accepted constitutional goals, there is considerable latitude for interpretation, emphasis, and the methods used to achieve these goals.

Over the last decade three federally sponsored studies were specifically directed towards a statement of our national goals: Goals for Americans, 1960, the report of President Eisenhower's Commission on National Goals; Toward a Social Report, a study sponsored by the Department of Health, Education and Welfare in early 1969; Towards Balanced Growth: Quantity with Quality, a report of the National Goals Research Staff issued July 4, 1970. The latter report did not attempt to set out specific goals to be sought, but rather it defined a series of questions that are of national concern and set forth possible consequences of several alternative directions.

In recent years, we have witnessed a greatly increased emphasis on individual welfare, political and social equality, and economic opportunity, as well as conservation. The present administration has clearly underscored the need for more attention to the above priorities and has

instituted a change in direction to achieve the same.* These priorities indicate the changed emphasis, and in some cases changed direction, from previous statements of this administration. These priorities appear also to reflect the deep-seated desires and concerns of the American people, which, although they may vary somewhat in intensity, are expected to endure over a long period of time.

In determining relevant priorities, it is necessary to consider two categories: explicit priorities -- statements of the level towards which the leadership of this country idealistically strives, and implicit priorities -- priorities that the leadership realistically seeks to attain. Explicit priorities are documented in Presidential papers, statements from executive departments and agencies, and congressional committee reports, whereas implicit priorities are found in executive budget documents and congressional allocations.

In considering explicit priorities, the criteria for selection was a consideration of the influence of the global ocean on the total dimension of the priority. Applying this criteria, the following administration and congressional priorities appear to be most relevant:

- <u>Restoration and Enhancement of Our Natural Environment</u>
  Preserving and restoring natural ecosystems

- <u>Economic Development and Prosperity</u>
  Fiscal policy to stimulate economic growth in the marine environment

- <u>International Cooperation</u>
  Increase peaceful cooperation and control of pollution, ocean exploration and development, space research, and other areas of international, environmental and technological concern.

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*The Report of the National Goals Research Staff, July, 1970, emphasized that modification and changes in national priorities is expected to be more common in the future. This suggests that any requirements which will be used to conceptualize EOS A/B should reflect the priorities of the administration incumbent at that time. Even though it is not possible at this time to define with certainty those future priorities, every attempt should be made, as emphatically stated in the report, to anticipate future emphasis.

Relevant implicit priorities are principally focused on questions of environmental concern. A further discussion of each of these principal categories of explicit and implicit priorities is discussed below.

Restoration and Enhancement of our National Environment

A series of messages by the President during 1970 and 1971 clearly established environmental improvement as a high national priority. For example, in July, 1970, a presidential message to Congress transmitting re-organization plans which established the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA), listed and defined major problem areas for priority action in the environmental area. The message called for a unified approach emphasizing interrelationships among air, water and land with regards to pollution waste disposal. It called for a program to identify the consequences of environmental degradation on the eco-system, and to identify those points in the eco-system where interdiction might be most tolerated. Prior to that, on May 20, 1970, the President sent a special message to Congress dealing with oil spills resulting from marine transportation. The comprehensive ten point program set out in the message included a broad spectrum of legislative proposals and administrative actions. The program also dealt with international concerns for prevention of pollution by tanker oil spills.

Additional presidential messages relevant to this priority were issued in February, April, May, July and August of 1970, and in February, 1971. In several instances, more than one message was sent to Congress during a specific month. Thus, considerable presidential effort has been expended toward programmetic implimentation related to restoration and enhancement of the natural environment.

Fiscal 1971 and 1972 federal budgets clearly show concentrations of dollars and personnel in the area of restoration and enhancement of our natural environment. Natural resource development and conservation received a major emphasis with pollution as the overriding concern. Water and air pollution control measures received particular emphasis with a nearly 200 percent increase from 1970 to 1972 (from 2. 5 to 4. 2 billion dollars). Increased personnel further reflect the administration's

intent to accent efforts to improve environmental conditions. In particular, with respect to the global ocean, action is assigned to several different federal departments including Commerce and the Environmental Protection Agency. Examination of the fulltime permanent civilian employees in each of these departments indicates:

- The Department of Commerce is increasing its personnel by 1200 individuals, most of whom will support the newly established National Oceanic and Atmospheric Administration (NOAA).
- The Environmental Protection Agency (EPA) has an estimated 1972 employment level of 8900, of which about 5800 represent transfers from other agencies. Another 3100 positions, 900 in 1971 and 2200 in 1972, will be provided as a net increase for this agency.

Economic Development and Prosperity

Although economic development and prosperity is primarily directed to terrestrial concerns, at least one facet bears directly on global oceanography. On October 23, 1969, the President sent to Congress a proposal for a new national maritime policy. The accompanying message called for a dramatic increase in the number of ships to be built over the next ten years, reflecting the President's concern that our merchant fleet remain an essential part of our economic system. Other relevant economic concerns include utilizing the ocean as a source for fresh water.

Water transportation is programmed for both dollar and personnel increases in fiscal years 1971 and 1972, with particular emphasis on the improved operating efficiency of the U. S. merchant fleet. Under the commerce and transportation category, increases are expected from 9. 3 billion in 1970 to 10. 9 billion dollars in 1972. The federal marine science program budget for fiscal year 1972 also reflects this increase under the transportation category.

International Cooperation

Certain priorities emphasizing international affairs continue to receive major emphasis, with some priorities identified for action programs. For example, both the bilateral assistance program, Agency for International Development (AID), and the multilateral assistance program, United Nations Development Program (UNDP), emphasize experimental programs and technical assistance in increasing the contribution of marine fish as a protein source for human consumption in developing countries.

In general, the various White House statements and congressional directives emphasizing international affairs relevant to global oceanography stress broadened international peace-time cooperation in areas of common concern, such as conservation and improvement of the environment, improved international trade, and reduction in loss and suffering from natural disasters.

In fiscal year 1972, international cooperation and collaboration is programmed for a slight increase (from 8.8 million to 9.3 million dollars), but not attaining the outlay during fiscal year 1970 (10 million dollars). Principal changes are found in the contributions of international organizations for marine science program activities and a slight increase in international fisheries commissions. No change is expected for AID.

1.2 PRIORITY IMPLEMENTATION

Numerous government agencies and programs are indirectly associated with the global ocean; a comprehensive inventory of such agencies and their programs and activities is summarized as part of Appendix A. Because of their direct relevance to the global ocean, four federal government agencies are of primary concern to this analysis: Department of Commerce, Department of Transportation, the Environmental Protection Agency, and the Department of Defense. Each agency has its priority needs dealing with ongoing programs and current administration and congressional priorities. Principal relevant needs of physical and biological nature of each agency are discussed below.

Department of Commerce

The principal programmetic action within the Department of Commerce lies with three branches of the newly formed NOAA.

The National Marine Fisheries Service (NMFS) of NOAA contributes to a large number of domestic and international programs planned to manage fisheries for conservation purposes and to assure that the resources will be maintained in a healthy condition. Thus, the NMFS is essentially responsible for developing adequate management techniques for insuring the continuity of the resource. Within this context, the relevant priority needs of concern to NMFS include optimum capabilities for resource assessment, resource prediction, resource management, and improved harvesting technology.

The National Weather Service (NWS) of NOAA is primarily responsible for reporting the weather and providing weather forecasts and storm warnings to the general public. It also develops and furnishes specialized weather services which support the needs of the maritime industries. Special marine forecasts and bulletins are issued on a regular basis to anyone with proper equipment to receive the transmission. These services are supported by a national network of observing and forecasting stations, communication links, and aircraft and satellite systems. Within this context the NWS is primarily concerned with advancing forecast capability through understanding of air/sea interaction (air/sea energy exchange). Major meteorological information requirements, a secondary interest, are also of concern to the NWS.

The National Ocean Survey (NOS) is primarily responsible for the accurate mapping of the bathymetry adjacent to and within nearshore areas of the contenental United States. Within this context, the NOS priority issues are concerned with optimum mapping techniques. NOS is interested in the sea surface phenomena primarily as it affects ship survey logistics.

Department of Transportation

Within the Department of Transportation, the principal focus of global oceanography is concentrated in the U.S. Coast Guard. The Coast Guard is primarily responsible for providing support services for the collection of oceanographic and meteorological data, monitoring potential ocean hazards and reporting their location, and law enforcement. Within this context, relevant priority needs are primarily concerned with optimum location and tracking of surface and subsurface hazards. Other information requirements are primarily in support of the regulatory functions.

Environmental Protection Agency

The principal functions of the Environmental Protection Agency (EPA) include the establishment and enforcement of environmental protection standards consistent with national environmental goals, the conduct of research on the adverse affects of pollution and on methods and equipment for controlling pollution. Within this context relevant priority needs of the EPA are primarily concerned with optimum monitoring, prediction and control of global ocean pollution.

Department of Defense

The Department of Defense is responsible for marine science and engineering programs dealing with national security. In particular, the Navy's programs are directed towards strategic deterence, underseas operations, anti-submarine and amphibious operations, mine warfare, ocean surveillance, protection of shipping and support of operations ashore. In pursuit of these programs, the Department of Defense allocated 225 million dollars in 1971.

As a secondary output, the Navy contributes towards a large number of civilian marine science programs. Specifically, the Navy's involvement in the Spacecraft Oceanography Program (SPOC) and TEKTITE are important contributions to global oceanography.

The Navy has a large number of relevant priority needs which overlap with many civilian requirements. Included in this list are environmental observation and prediction, marine surveys, mapping, charting, geodesy, ocean engineering, and man-in-the-sea.

1.3 INDUSTRIAL PRIORITIES

Priority issues of the fishing, transportation, and offshore petroleum industries are the principal global ocean industries. This is based on a combination of total expenditures and/or income and the total number of persons involved or employed by the particular industry. Table 2-1 presents a summary of pertinent data for each principal industry. Although the fishing and offshore petroleum industries are largely confined to the U.S. continental shelf, their priority needs are considered under this analysis because these industries are directly or indirectly affected by phenomena which are of mesoscale or larger dimension.

1.3.1 Fishing Industry

The total U.S. fishing industry is comprised of 30 or more separate fisheries which are dependent upon several hundred species of finfish and shellfish. These fisheries produce an annual catch worth over 600 million dollars (1970) in unprocessed form. Processed this represents more than 1 billion dollars in products.

Table I-1. Principle Global Ocean Industrial Users
(date of information given in brackets)

Industry	Income (million dollars)		Number Persons Employed	Comments
Transportation	4,000	(1969)	87,000 (1967)	High seas transportation only
Offshore Petroleum	2,350	(1968)	30,000 (1967)	Persons employed computed from dollar/person ratio for entire industry
Fishing	602	(1970)	128,000 (1965)	Persons employed do not include 87,000 shore workers

Demand for fisheries products in the U.S. has increased dramatically in the past two decades. At the same time, domestic production has remained essentially static. Continued increase in demand has and will continue to place severe stress on the domestic industry to increase their output.

The advance of a given fishery is only partially dependent on scientific progress. Environmental and institutional peculiarities pose problems in certain locations, and the effects of fiscal, legal and regulatory problems frequently present severe restrictions to a viable fishing industry. Considering only the environmental problems, relevant priority needs include:

- Optimum location, tracking and identification of commercial species
- Optimum harvesting, including the concentration and control of species, preferably on a selective basis
- Transporting catches from fishing grounds to processing facilities at sea or ashore.

1.3.2 Transportation Industry

In the last decade, attitudes towards the progress of the U.S. merchant fleet were generally apathetic. Due to a number of complex factors, our merchant fleet dwindled from a post-war high of 3,696 ships to a current 967 ships. Of these, only 650 are involved in foreign trade.

The U.S. generates almost one-third of the total world trade. Unfortunately, less than 7 percent in commerce tonnage of our foreign trade is carried by the U.S. merchant marine.

The federal government has recently proposed an aggressive solution to developing a modern, efficient merchant marine fleet. This will include improvement of the fleet, improvement of shipboard efficiency and economy and the establishment of a new rapport between government and labor. The overall program provides for the building of 30 ships per year, or an additional 300 ships over a ten year period.

The transportation industry is faced with three relevant priority needs:

- Optimum Scheduling

  Implies a requirement for long term environmental information in order to construct optimum routing and timing for various seasons and regions

- Contingency Scheduling

  Implies a requirement for short term environmental information on transient phenomena necessitating departures from optimum scheduling

- Emergency Planning

  Implies the need for instantaneous information in order to respond to disasters at sea..

1.3.3 Offshore Oil and Gas Industry

The petroleum industry has invested over 7 billion dollars in offshore exploration and exploitation along the continental U. S. Although revenues have not as yet equalled expenditures, the U. S. petroleum industry still regards the offshore resources as its last frontier.

Exploratory wells have been drilled from floating rigs in waters deeper than 600 feet, and exploitation wells have been drilled from huge fixed platforms in waters deeper than 300 feet. It is anticipated that as wells are drilled in deeper water, the operation of the drilling rig will require much more extensive environmental information in order to maintain continuity of operation as well as insure safety of the platform crew. Relevant priority issues which currently face the offshore oil and gas industry are centered around optimum utilization of drilling platforms, and transportation of the petroleum products to shore facilities. The latter priority needs are identical to those facing the transportation industry.

1.4 RESEARCH AND EDUCATION PRIORITIES

University interest in the global ocean has been primarily towards basic research. In attempting to understand the physical, chemical, biological, and geological characteristics of the global ocean, the researcher has directed his efforts towards being able to model and predict changes in the characteristics of the global ocean. This requires a broad range of environmental data.

The demand for oceanographers has increased dramatically over the past decade, and a corresponding increase in the number of academic institutions offering oceanographic studies has resulted. Today there are at least 77 institutions* in the United States which devote time to study of the marine sciences. Research and education in the university go hand in hand, and such federal programs as the Sea Grant Program support this intimate relationship. Although federal research and development program expenditures show an equivalent increase of 20 percent from 1971 to 1972, the absolute amounts are relatively small (from 104.4 to 131.4 million dollars). However, support by the National Science Foundation for a broad range of environmental research will increase by 66 million dollars, or nearly 60 percent from 1971 to 1972.

Priority needs relevant to oceanography which can be appropriately stated for universities include two major headings: basic research and problem oriented research. Basic research implies a broad overview of all other categories, but realistically must be limited to the availability of personnel and funds. Presently, relevant research problems involved with the global ocean are primarily directed towards air/sea interaction, biological production, and geochemical and geophysical processes. Problem oriented research is primarily directed towards two aspects, statistical modeling (based on empirical knowledge) and mathematical modeling (based on theoretical knowledge). Both lead to increased predictive capability. In all cases, a broad range of global environmental information is the principal contributor towards advancing research.

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* A comprehensive listing of universities relevant to the global ocean is given in Appendix A.

1.5 INDIVIDUAL AND GROUP PRIORITIES

How individuals and groups relate to the global ocean, in large part, determine where they place global oceanography in relationship to their many other priorities. The influence which the individual citizen exerts over the oceans is perhaps difficult to visualize. However, collectively, individuals exert a tremendous impact on the ocean. An example may dramatize this fact.

One of the largest fisheries in this country and, in fact, the only fishery which depends upon an open ocean resource is that for tuna. In the past 20 years there has been a rapid increase in the acceptance and subsequently the demand for tuna products. At the beginning of that period, the supply of tuna much exceeded the demand, one manifestation of which was the rather low price which canned tuna brought in the market place. However, through advertising and acceptance, the demand for tuna in this country has increased dramatically so that now the demand approaches, and may soon exceed, the amount of tuna which can be harvested from the ocean on a continual basis.

Tuna occur in various parts of the ocean in discreet schools which compose discreet populations. Each year, individual mature females in each school lay thousands of eggs. However, between the period that the eggs are laid and the tuna reach an age (size) where they can join a school, there is a tremendous attrition due to numerous environmental and biological factors. Thus, only a few tenths of a percent of the eggs laid each year are represented by harvestable tuna joining a school.

It is evident that all that is required to replenish any given school are the eggs produced by one or two females in that school. However, for genetic reasons, over the long term it is necessary that many females produce many eggs so that a large genetic pool remains in the few eggs which survive to adulthood. Obviously, if all tuna in the ocean were harvested in any given year, then none would remain to replenish the oceans. At the same time, the production of tuna through the processes described is sufficient each year so that a large excess of fish exists, and this excess is available for exploitation by other oceanic organisms as well as by man. This excess in number which represents the difference between

the total number of tuna in any population, and the total number of tuna in that population required to replenish the population at a genetically stable level may be called the maximum sustainable yield (MSY).

In order to optimally use the tuna resource, fishermen should fish at the MSY. Although individuals may place a tremendous demand on tuna resources, there is a maximum limit to the number of fish that can be harvested in any given year. The fact that the ocean has a finite resource capability runs counter to the general attitude in this country that the ocean is so vast that it holds an infinite supply of fish. It is therefore important to each individual that a reasonable estimate be made each year of MSY if the general public is going to continue to demand and receive a continuing supply of tuna products over the coming years.

This same argument and logic applies to all of the food resources harvested from the ocean. That is, there is an excess in numbers over what is required to sustain the population and that excess is available for exploitation by man. But if that exploitation leads to the harvesting of more than the excess, then man has jeopardized the continuity of that resource.

The overriding individual and group priority, as demonstrated by the above example, is to gain knowledge and understanding of the entire global ocean system. This refers not only to the living resources, but to the non-living resources as well.

In the past, individuals and groups have generally taken the position of dominance over global ocean resources and the environment. That is, they considered them to be materials to be exploited. When there were relatively few people on the earth, such exploitation could be tolerated. But with a burgeoning population this stance is no longer acceptable.

1.6 GLOBAL OCEAN PRIORITIES

Having analyzed the priorities of the four institutions originally described: government, industry, academia, and the public, there appear to be several overlapping and interrelated priorities which can be summarized and considered as global ocean priorities.

It is overwhelmingly evident that of the administration and congressional priorities, only restoration and enhancement of the natural environment is represented both in the expression of concern and allocation of resources, and hence requiring of immediate attention. The emphasis of

the EPA, as well as major compenents of NOAA, support this contention. The remaining administration and congressional priorities, including stimulating economic growth and increasing international cooperation, will certainly derive secondary benefits from emphasizing environmental concern, but of themselves do not have sufficient support to warrant consideration as a global ocean priority.

Although the general public has priorities, these are often difficult to visualize, and even more difficult to document. The previous example demonstrates that the public does have a direct interest in the proper management of the marine environment, if it is to continue to be a source of living resources demanded by large segments of the population.

In that the concept of management entails the asking of very basic questions concerning the structure and dynamics of the marine ecosystem, the data derived can also be utilized to satisfy some, if not all, of the demands of the scientific community.

Thus, it becomes evident that a consideration of national priorities, while seeming to ignore two special interest groups -- the general public and the scientific community -- has in this instance provided an orientation answerable to both. The direction implicit in restoration and enhancement of the natural environment, as applied to the marine environment, will result in a program relevant to all three -- meeting administration and congressional needs; being responsive to the general public; and satisfying the basic information requirements of the scientific community.

Unfortunately, individuals and groups are just beginning to realize the implication of what has been done to the global ocean resources and environment. Alterations of the living and non-living components which make up the various ecosystems are occurring continuously. Since interactions are so numerous and so crucial to the operation of the system, small changes in one part of an ecosystem are likely to be felt and compensated throughout the system. The consequences are often catastrophic.

Thus, it is apparent that individuals and groups are shaped to a great extent by their interaction with the environment. Man's physical nature, his mental health, his culture and institutions, his opportunities for challenge and fulfillment, his very survival -- all of these are directly related

to and effected by the environment in which he lives. They depend on the continued healthy functioning of the natural systems of the earth.

A third special interest group, industry, generates priorities which require a somewhat different, but compatible, orientation. Within the context of ensuring profitability, the three major industries discussed are deeply concerned with resource supply and operational efficiency. These factors are in turn related to resource and environmental exploitation frequently involving degradation of the environment.

Thus, the priorities can be conveniently summarized in three major categories:

- Monitoring and prediction of physical phenomena

  Understanding and predicting those phenomena which determine the physical environment of the global ocean ecosystem

- Management of living marine resources

  Understanding and predicting those phenomena associated with the living component of the global ocean ecosystem

- Detection, monitoring and control of global ocean pollution

  Monitoring and controlling those manmade phenomena which significantly perturb the natural system.

Realizing that none of these three stands alone, it is also desirable to remain cognizant of the interrelationships between these three categories.

1.6.1 Monitor and Predict Physical Phenomena

Meeting this priority will satisfy the need for optimum ship scheduling, predicting departures from scheduled routing, and emergency planning. It will partially satisfy the need of optimum utilization of drilling platforms as well as offshore mapping. It represents the ultimate goal of much of the directed research efforts of marine scientists. This priority will contribute to management of the marine ecosystem by partially supplying the information required to understand the ocean environment. Information derived will contribute to knowledge of air/sea interaction and thus improve weather forecasting ability.

1.6.2 Manage Living Marine Resources

Meeting this priority will satisfy the need for optimum assessment, harvesting and management of commercial fishes. This priority is crucial to the preservation of the marine ecosystem. Every component of the complex food web comprising life in the ocean effects the status of the remaining components. Whether the organisms are of commercial or aesthetic importance, is of no direct importance to man, they are important to each other. Serious alteration of any group of organisms will affect others to a greater or lesser extent. Thus the need exists to understand the system as a system, and in all its intricate array. The need to conserve the species upon which man is dependent implies the need to conserve all living components. The basic research needs of that portion of the scientific community concerned with marine life must be fulfilled so that the results of that research can contribute to the understanding necessary to conserve the living resources.

1.6.3 Detect, Monitor and Control Global Ocean Pollution

Perhaps the most serious threat to both the biological and physical resources of the ocean, and to man himself, is the increasing rate of addition of pollutants to the marine environment. These pollutants can be considered in two broad classes:

- Substances foreign to the ocean, generally manmade, which are usually present in minute amounts but which, due to their artificial nature, cause severe perturbation even when present at extremely low levels

- Substances not necessarily foreign to the ocean, but generally present in limited amounts. These become pollutants when added in larger quantities than the system can normally handle.

The information needed to predict, monitor and control these substances may differ in nature, but their determination is essential to the conservation of the ecosystem.

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